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OUTLINING A FRAMEWORK FOR THE USE OF ICT IN DISASTER MANAGEMENT

by

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The purpose of this qualitative study is to reach a deeper understanding of the interrelations among people, processes, organizations, and technology in humanitarian assistance and disaster relief missions in order to develop a framework for organizations considering the usage of ICT in disaster relief operations.

The research contributes to the body of knowledge by examining the problems and influences appearing with use of ICT in a command and control approach. Deeper understanding of the interrelations and risks will enable non-governmental organizations as well as military and other governmental organizations to take effective measures to prepare for the use of ICT and the leveraging of command and control in disaster relief operations. Improvement of command and control will have an immediate impact on disaster relief efforts.

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OUTLINING A FRAMEWORK FOR THE USE OF ICT IN DISASTER MANAGEMENT

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LIST OF ACRONYMS AND ABBREVIATIONS

C2	command and control
CO	central office
COI	community of interest
COP	common operational picture
DHS	Department of Homeland Security
DOD	Department of Defense
FEMA	Federal Emergency Management Agency
GIS	global information system
HA/DR	humanitarian assistance/disaster relief
HSOC	homeland security operations center
ICT	information and communication technology
ISR	information, surveillance, and reconnaissance
MERS	mobile emergency response support
NIMS	national incident management system
NRP	national response plan
OC	operation center
PSTN	public switched telephone network
USDA	U.S. Department of Agriculture

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I. INTRODUCTION

In recent years, the United States of America and other nations have been confronted with disasters, which have had a huge emotional and economic impact. In order to counter these impacts, organizational and international cooperation has grown. This cooperation results in complex coordination efforts and even more in an increased demand for information. Another fact of natural disasters, especially in more developed countries are the huge impact they have on the basic infrastructure. In such cases, the disaster disenables the information flow right at the beginning and impedes coordination. Research indicates potential benefits of applying information and communication technology (ICT) to the field of disaster relief by establishing communication in a devastated environment and, therefore, enabling distribution of and access to information in a timely manner (Coyle & Meier, 2009; Wentz, 2006). On the other hand, research has shown that applying technology does not necessarily leverage the command and control accompanied by an improvement of the relief efforts (Christman, Kramer, Starr, & Wentz, 2006; Lundberg & Asplund, 2011; Wentz, 2006).

Applying technology in any kind of command and control approach has interrelations with other factors, so they may cancel each other out, or at least hamper the intended benefit. These risks, coming out of the interrelations, have to be identified in advance in order to prepare for the usage of ICT. Research has shown that people, processes, organizations, and technology interact with each other (Alberts & Hayes, 2003; Alberts & Hayes, 2006; Comfort, Ko, & Zagorecki, 2004; Comfort & Kapucu, 2006). For example, the fact that numerous organizations participate in humanitarian assistance/disaster relief (HA/DR) operations in a dynamic environment encourages a decentralized command and control approach to effectively help the casualties. By contrast, the hierarchical structure of networks and the access to all kinds of information up to the highest command levels suggests a centralized approach. The different demands of both approaches may influence the outcome.

Organizations are interested in leveraging command and control in disaster relief operations in order to help the victims quickly and more effectively. To reach this goal,

the usage of ICT promises a benefit to the approach. An understanding of the interrelations involved will enable the organizations to adapt to the dynamic environment, apply ICT in a meaningful way, and leverage the command approach. Furthermore, ICT development should be focused on the needs of a collaborative approach, rather than on improving ICT capabilities without this focus (Asimakopoulou & Bessis, 2010).

A. RESEARCH STRUCTURE

This section identifies the central problem driving this research as well as the questions investigated. Moreover, it defines the intended purpose of conducting this research and the potential contributions of the resulting framework to the field of disaster relief. It is also important to note a limitation of this study, which is that the researcher has no experience in disaster-relief operations and that no interviews have been conducted during the data collection process. Proving the framework against a case report should increase validity to mitigate these limitations.

1. Problem Statement

The problem driving this research project is that initial disaster relief operations are characterized by chaos and devastation and, therefore, a lack of information and reduced situational awareness. The huge number of participants responding to disasters often impedes the overall effort. Furthermore, the fact that different organizations approach the problem in their individual ways, and more importantly, using their individual processes, increases the set of coordination problems. Moreover, the number of individuals participating in each organization, all of whom have different mindsets, understandings, and behaviors, contributes to the problem.

Applying modern information and communication technology has become an essential part of HA/DR operations. ICT promises a way to distribute and access information in a timely manner, but the other constraints previously mentioned will still interfere. It is necessary to understand the interrelations between people, processes, organizations, and technology in order to take all necessary steps to prepare for the effective usage of technology in the field of HA/DR missions.

2. Purpose

The purpose of this qualitative study is to reach a deeper understanding of the interrelations between people, processes, organizations, and technology in HA/DR missions in order to develop a decision framework for organizations considering the usage of ICT in disaster relief operations. The research contributes to the knowledge by examining the problems and influences appearing with use of ICT in a command and control approach. Deeper understanding of the interrelations and risks will enable non-governmental organizations as well as military and other governmental organizations to take effective measures to prepare for the usage of ICT and the leveraging of command and control in disaster relief operations. Improvement of command and control will have an immediate impact on the disaster relief efforts.

3. Research Questions

The following questions served to guide this research:

- How do people, organizations, and processes interrelate in disaster relief missions, and how can organizations prepare for the effective use and procurement of technology?
- What are the limitations illustrated by people, processes, and organizations in the use of technology?

B. POTENTIAL BENEFITS

Organizations, like the U.S. Department of Defense (DOD), may benefit from a better understanding of how people, organizations, processes, and technology interfere but may also cooperate in disaster relief operations. The developed framework will assist governmental and non-governmental organizations to determine the level of technology to apply in a mission and how to prepare for effective use of that technology. As the use of technology increases, the knowledge of how to effectively procure and deploy technology becomes more and more important.

C. THESIS ORGANIZATION

In addition to this first chapter, which outlines the background and research focus, this thesis consists of four other chapters. Chapter II contains the literature review, which focuses on a definition of disasters and the phases of disaster management, the role of ICT in disaster relief, and the foundational concept of command and control. Understanding the different phases of disaster management and the command and control model introduced builds the foundation for this study.

Chapter III describes the chosen application of the case study method in this research. The study represents a holistic Type I case study (Yin, 2014, p. 50). The components of research design, as well as the criteria for judging the quality of the design will be introduced (Yin, 2014, pp. 29–49). The actual case study is presented in Chapter IV. This chapter introduces the case of the Hurricane Katrina and the respective disaster management, followed by a study of the role of ICT and the interactions between people, organizations, processes, and technology in this situation. Finally, a framework is derived to assist organizations in decision-making for the use of ICT. The thesis concludes with Chapter V, which summarizes this study and offers recommendations for future research.

II. LITERATURE REVIEW

This chapter focuses on a definition of disasters and the phases of disaster management, the role of ICT in disaster relief, and the foundational concept of command and control. Understanding the different phases of disaster management and the command and control model introduced builds the foundation for this study.

A. THE NATURE OF DISASTER

Disaster, in order to distinguish it from emergencies, is characterized by the huge number of people it affects and the range of damage to property and livelihoods it causes, exceeding the capacities and capabilities of conventional emergency institutions like the police and fire departments (Haddow, Bullock, & Coppola, 2011; UN Economic and Social Commission for Asia and the Pacific [UNESCAP], 2010). Moreover, disasters are characterized by not only their initial huge impact but by cascading effects that worsen the situation, causing more damage and overwhelming local authorities (UNESCAP, 2010). For example, earthquakes may cause bridges to collapse, which causes even more casualties, further damage to other infrastructure, and major implications for responding to the resulting accidents. Therefore, disasters can be seen as the ultimate challenge for emergency management, which will be defined in detail later (Auf der Heide, 1989).

1. Causes of Disasters

Disasters can be categorized into two main categories according to their cause: natural and technological (Haddow et al., 2011). Natural disasters are threats to human population and property caused by meteorological, hydrological, climatological, and geophysical processes, such as floods, earthquakes, and hurricanes (Haddow et al., 2011). Technological disasters are caused by the failure or misuse of technology (Haddow et al., 2011). This failure may occur accidently (for example, a dam breaks) or due to the flawed application of technology. The latter type may be caused purposely, for example, as a result of terrorism. Technological disasters impose a higher human factor, intentionally or unintentionally, and therefore pose a lower predictability than natural

disasters, which, to a certain degree, can be predicted (Auf der Heide, 1989; Haddow et al., 2011).

2. Phases of Disaster Management

Most researchers agree that disaster management, which addresses the response to disasters, consists of a cycle involving four core phases as delineated in Figure 1. Appropriate actions at all phases of the management cycle will enhance the performance in future cycles and reduce the risks of hazards and mitigate the impact of disasters (Auf der Heide, 1989; Haddow et al., 2011, pp. 97–250; UNESCAP, 2010; Waugh & Streib, 2006). Authors, like Haddow et al., introduce a fifth phase, namely communication (Haddow et al., 2011). In this paper communication, and especially through technological means, is seen as part of all other phases and will therefore not be seen as an individual phase. Moreover, it is perceived as an integral part of the stages. Although the distinction between several stages of the management cycle is sometimes blurry, due to the intertwined activities happening in distinct stages, in the following paragraphs the core phases will be briefly introduced (Haddow et al., 2011; Waugh & Streib, 2006).

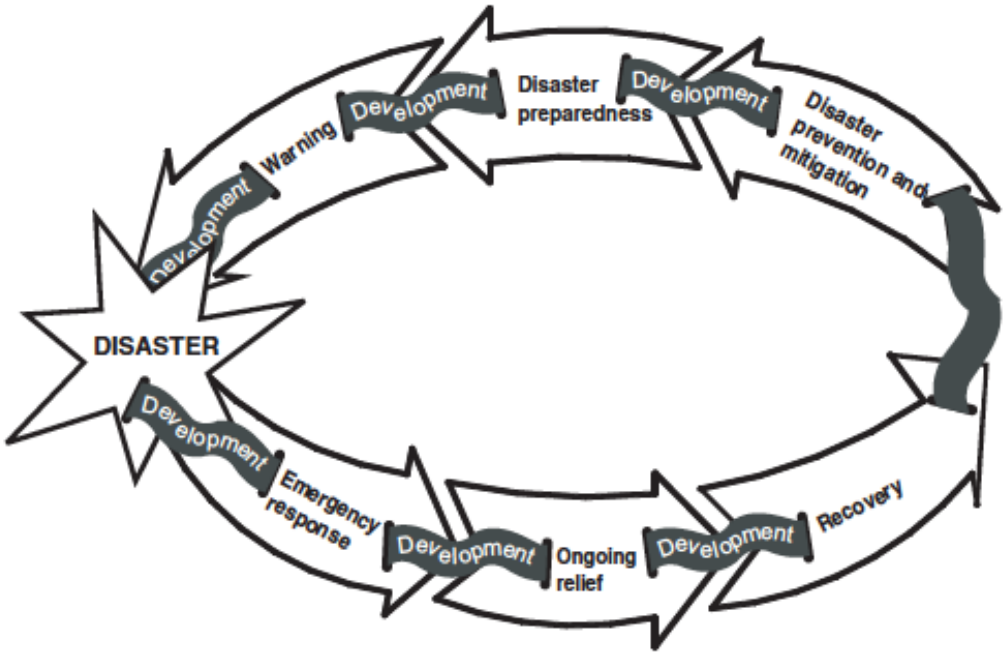


Figure 1. Disaster management cycle (from UNESCAP, 2010).

Mitigation: Mitigation can be described as all means intended to reduce, or even eliminate, the risks to people and infrastructure from previously discussed hazards (Haddow et al., 2011, p. 69). Arguably, eliminating all risks from such hazards is not reasonable. Elimination of hazards would imply that it is possible to prevent disasters entirely, or to move population and infrastructure in such a way that they are no longer prone to such disasters (UNESCAP, 2010). Instead, mitigation aims to provide long-term solutions to reduce the impact of disasters and, as of today, the efforts are mainly driven by previous disasters. Therefore, these actions are intertwined with the recovery stage (Haddow et al., 2011, p. 70). Especially in this stage many participants involved in the process, such as politicians and land-use planners, are not traditionally involved in disaster management (Haddow et al., 2011, p. 75). All these participants are involved mainly in identifying and mapping hazards and provide solutions by constructing applications, planning of land-use, and providing incentives to mitigate the risks exposed (Haddow et al., 2011, pp. 75–80). Consequently, the focus of mitigation efforts is based at the local level, because most decisions about development are made at this stage, and therefore, they are most effective (Haddow et al., 2011, p. 75).

Preparedness: Preparedness can be seen as an overarching phase because it aims to achieve a sufficient level of readiness to cope with any kind of disaster (Haddow et al., 2011, p. 97; UNESCAP, 2010). This goal is approached by planning, training, and providing equipment to improve the technical and organizational capabilities of governments, organizations, and communities (Haddow et al., 2011, p. 99; UNESCAP, 2010). Looking at the variety of hazards it may be hard to plan accordingly, because planning has to involve a variety of disaster scenarios. Arguably planning can only be effective if it focuses on the hazards most likely in a specific area. Training is necessary to gain the ability and to prepare organizations, as well as individuals, to handle specific challenges (Haddow et al., 2011, p. 101). In particular, training is important in disaster management, because it helps to develop themes of coordination and provides exchange of information, or even more important, it offers the possibility to establish information exchange among different participating organizations. Last, the right equipment is necessary, and therefore, procurement faces the same problems as, or can be seen as a

result of, proper planning for specific hazards. Furthermore, under the scarcity of sufficient funding, procurement decisions have to be considered carefully. In regard to this paper the procurement of ICT becomes relevant and is of major concern, due to the ability to provide means to collect, analyze, and disseminate information.

Response: Arguably this phase is what most people would assume is disaster management, or at least it is the most visible part of the management cycle (Haddow et al., 2011). Response is the phase in which organizations react to a disaster by assisting the population in maintaining life, securing health, and reducing the impact of a disaster (UNESCAP, 2010). First responders to disasters are typically local authorities like police and fire departments, and when the emergency exceeds the capabilities of these organizations, they request help (Haddow et al., 2011). The effectiveness of response and/or the range of impact of a disaster will highly depend on other steps in the management cycle: mitigation and preparedness (UNESCAP, 2010). Responding to disasters effectively depends on the level of training, logistics, and communication among all participating agencies, and all of them being grounded in these two steps (UNESCAP, 2010). The impact of ICT is particularly profound in this more than any other phase (Reddick, 2011).

Recovery: To determine the start and end of the recovery phase might be the hardest of all four stages. There is no distinct point in time where response switches over to recovery (UNESCAP, 2010). Furthermore, due to the long time efforts put into recovery it might also be hard to determine the end of recovery and the beginning of mitigation and preparedness. But due to these facts, the recovery phase provides valuable inputs for the other phases (UNESCAP, 2010). For example, results of current disasters can be used to provide valuable data for further hazard analysis and modeling and the establishment of warning systems (Reddick, 2011). Moreover, tracking the logistics and related efforts necessary to cope with one disaster provides valuable inputs to similar challenges, if they are collected, processed, and distributed accordingly.

B. INFORMATION AND COMMUNICATION TECHNOLOGY

Information and communication technology deployed to a disaster relief operation promises a high value to coordination efforts (Coyle & Meier, 2009, p. 27; Wentz, 2006, p. 2). The dynamic and unclear situation at the beginning of a disaster relief operation demands high coordination. Moreover, the large number of participating organizations in disaster relief operations needs coordination. Even the more localized event, in terms of affected area, of the 9/11 attack involved a total of 456 organizations in the response operation (Comfort & Kapucu, 2006). Information technology is able to connect all these organizations despite the fact that in some disasters the communication infrastructure is significantly affected (Comfort & Kapucu, 2006; Lundberg & Asplund, 2011; Wentz, 2006, p. 48).

A number of different possibilities exist to apply ICT in disaster relief and in different stages of disaster relief (*Disaster management handbook* 2008), ranging from terrestrial radio communication, terrestrial wireless communication (like hastily formed networks), and commercial satellite communication to social networks and Internet portals (Denning, 2006; Marrella, Mecella, & Russo, 2011; Nelson, Steckler, & Stamberger, 2011; Wentz, 2006, p. 48). Applying all these different technologies to disaster relief missions carries the threat of interference, because there is limited bandwidth (Wentz, 2006, p. 51). Moreover, the incompatibility of different civil and military systems affects the outcome of applied ICT (Christman et al., 2006; Wentz, 2006). Common to all research about ICT in HA/DR missions is that information and communication technology is a necessary enabler of inter- and intra-organizational communication and information exchange (Christman et al., 2006; Denning, 2006; Denning & Hayes-Roth, 2006; Lundberg & Asplund, 2011; Wentz, 2006). On the other hand, research has also shown that applying technology to the field of disaster relief is not a solution at all. Regardless of what the technical connection is able to transmit, it is still a human who decides whether or not the data will be distributed. The human factor in applying the technology is critical and strongly impacts performance of disaster relief operations (Christman et al., 2006; Denning, 2006; Denning & Hayes-Roth, 2006; Lundberg & Asplund, 2011; Wentz, 2006)

Research has definitely shown that ICT enables information exchange in disaster relief operations. Furthermore, the need for information exchange in order to manage a disaster is necessary. Although a lot of factors have been examined, it remains unclear how to apply ICT to this field and use it effectively. It has been shown that the use, or misuse, of ICT has an impact on performance. The development of even more systems to leverage the role of ICT in disaster relief is ongoing. This research addresses the interrelations between ICT inside the command and control approach and a way to determine and prepare for its effective use. Furthermore, it could provide a foundation for applied ICT in collaborative approaches in HA/DR command and control.

C. COMMAND AND CONTROL

In disaster relief missions, command and control (C2) and management can be understood as the same. In this thesis we also will use both terms interchangeably, but the following paragraphs will mainly focus on command and control, because the fundamentals introduced are based on research conducted in a military environment. Command and control can be briefly described as aligning all efforts of multiple entities to reach a common goal (Alberts & Hayes, 2006, p. 32). Or, as ISO 22320 defined command and control as:

> activities of target-orientated decision-making, assessing the situation, planning, implementing decisions and controlling the effects of implementation on the incident. (ISO 22320, 2011)

The approaches to command and control have changed over time, especially under the influence of new technologies, but the overall aim remains the same as mentioned previously (Alberts & Hayes, 2006, p. 31). Moreover, command and control deals with people, organizations, processes, and technology, or more specifically, how they interfere with each other, in order to reach a desired goal. More and more research has been conducted related to command and control in disaster relief operations. Common to this research is the topic of the coordination efforts among multiple organizations (Bharosa, Lee, & Janssen, 2010; Comfort & Kapucu, 2006; Comfort & Haase, 2006; Gao, Wang, Barbier, & Liu, 2011).

Research shows that relief after a disaster can only be managed by a multi-organizational approach. Only the cooperation of many institutions is able to overcome the huge impact of disasters, but most often these organizations are not able to coordinate their efforts (Chen, Sharman, Raghav Rao, & Upadhyaya, 2008; Comfort et al., 2004). One suggested reason for a lack of coordination is the unpredictable and complex situation, involving different organizations that may have never worked together before (Bharosa et al., 2010).

Furthermore, research has shown important insight into how organizations apply their resources to such challenges. Most often, large organizations, like military forces, use hierarchical structures and tend to maintain their processes in HA/DR in the same manner (Comfort & Kapucu, 2006). Information technology, although enabling a broad distribution of information, is not capable of leveraging another type of command and control. One reason for this is that civil-military boundaries hamper the information exchange between organizations even more (Comfort & Haase, 2006; Denning & Hayes-Roth, 2006).

Recent research and references from 2003 to 2006 indicates that an overarching understanding of requirements and a common intent enables all participants to act independently and reach the goal of a mission effectively (Alberts & Hayes, 2003; Comfort et al., 2004). Both studies come to the same solution, although they use different terms. Alberts and Hayes (2003) call this concept "self-synchronization," whereas Comfort et al. (2006) refer to "auto-adaptation." However, both present evidence that to enable a more efficient command and control in complex and dynamic situations, the individual has to be strengthened (Alberts & Hayes, 2003; Comfort et al., 2004). "Individual" in this case means not only one person; it can also be one organization in a huge community. Empowering of the individual under a common intent will help to better assign the overall efforts. In context of this research, understanding command and control is necessary because it outlines the problems associated with disaster challenges and more specifically to their complexity and dynamic (Alberts & Hayes, 2006). For this study the approach from Alberts & Hayes was chosen due to the fact that this approach mainly focuses on technological advances and their effects on collaboration endeavors, of

which disasters arguably are an example (Alberts & Hayes, 2003). Furthermore, the concept fits into this study, due to its definition that command and control does not necessarily require (Alberts & Hayes, 2006):

- Unity of command (an individual in charge)
- Unity of intent (an intersection of goals)
- Hierarchical organizations
- Explicit control

This emphasizes the specific environment in which disasters are encountered, by a variety of groups, with different forms of organization and culture, and with sometimes-different intents. The following paragraph will introduce a basic concept of command and control to encourage a better understanding of the process itself. Following that, we will introduce the concept from Alberts and Hayes (2003, 2006) in more detail.

1. The OODA Loop

The OODA loop (for Observe, Orient, Decide, Act) was intentionally developed to explain coherencies and procedures inside the decision-making process of military forces, or more specifically, the decision-making of fighter pilots (Boyd, 1987). The approach from Boyd, as outlined in Figure 2, starts with the observation of the physical environment. These observations are then set into context as depicted, for example, with cultural traditions, new information, and previous experiences. This orientation phase allows the individual to make a decision, based on his interpretation of the information gathered.

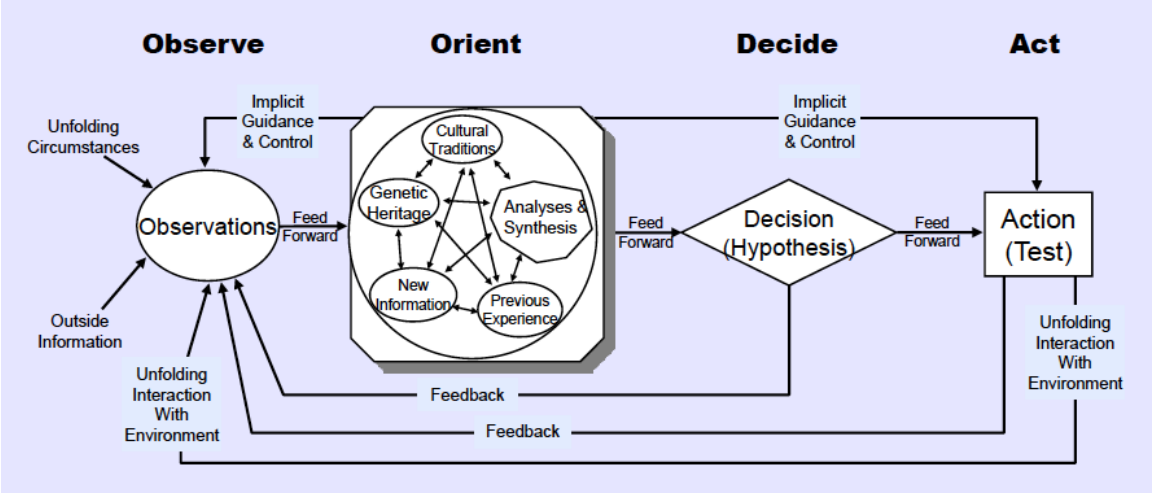
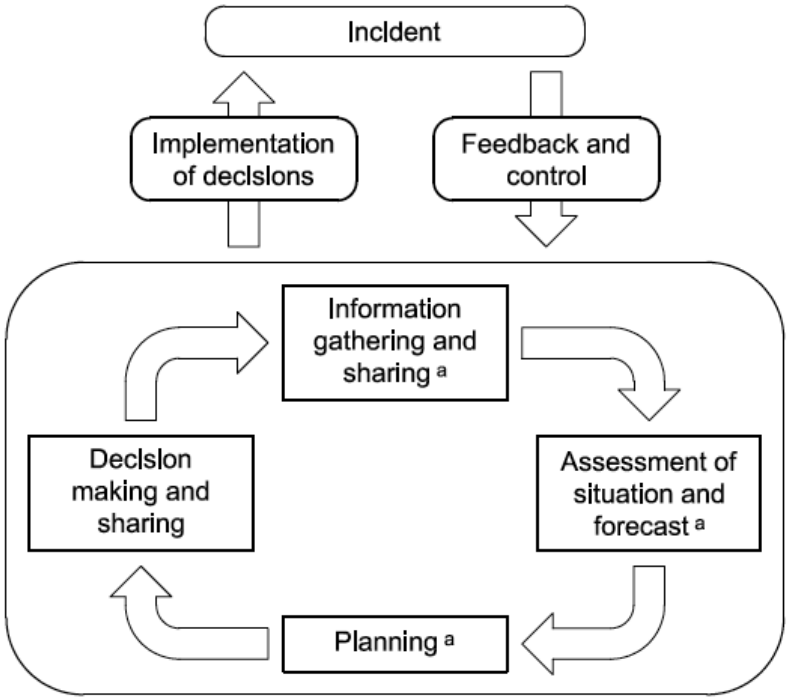


Figure 2. OODA Loop sketch (from Boyd, 1987).

"Decide" means to derive a course of action and translate this action into a commander's intent. The last phase of the loop, "Act," puts this intent into action. After conducting this process the changes to the environment have to be observed again to adjust follow-on action and assess success. The OODA loop, as described in the previous paragraph, has its advantages in easily defining decision-making and the steps involved to reach a decision. This approach has been widely used, especially in military forces around the world, and not just for fighter pilots, due to its robustness and applicability. For the purpose of this study we mention two weaknesses in the OODA loop addressed by Alberts and Hayes (2006), namely that the OODA loop focuses on individuals. Respectively, it assumes that decision-making in larger formations, like in disasters, is made under a single intent and decisions are coordinated seamlessly among all participants. Therefore, the OODA loop is not sufficient to examine the processes in disaster management, but provides a good introduction to the topic of decision-making and, as can be seen in Figure 3, is also incorporated into the ISO 22320 definition of a command and control process for a single hierarchical organization in disaster management.



a With limited need for coordination with partners outside the organization.

Figure 3. Example of command and control process (from ISO 22320, 2011).

2. Conceptual Model of Command and Control

The model developed by Alberts and Hayes (2006) describes command and control in a somewhat different way from our previous discussion, and its purpose was especially to explore new command and control approaches (Alberts & Hayes, 2006, p. 49). Most often command and control are understood as two different aspects, and often command is described as "art" whereas control is referred to as "science" (Alberts & Hayes, 2006, p. 15). Alberts and Hayes understand both as part of the process, and in contrast to the output of the OODA loop process, which is defined as a decision, the command process in their approach delivers command intent (Alberts & Hayes, 2006, p. 52). This has two major implications; first it can be applied to a number of participants instead of an individual. Second, by providing an intent for the mission, there is a basis for the remainder of the process, which makes the result much more valuable (Alberts & Hayes, 2006, pp. 38–40).

a. Key Functions

Most often, successful command and control (C2) is determined by its simplest definition of mission accomplishment, which in fact is determined by the definition of the mission itself (Alberts & Hayes, 2006, pp. 32–33). Arguably, this might lead to a false perception when, for example, the definition of the mission is flawed. The accomplishment might be considered successful because the goal was reached, although the mission cannot be perceived as successful looking on how this mission was fulfilled. Therefore, the functions of C2, or more accurately, the quality of how well the functions are carried out, can be used to determine success more appropriately (Alberts & Hayes, 2006, pp. 32–33).

Thus, Alberts and Hayes identified seven essential command and control functions (Alberts & Hayes, 2006, p. 47):

- Establishing intent
- Determining roles, responsibilities, and relationships
- Establishing rules and constraints
- Monitoring and assessing the situation and progress
- Inspiring, motivating, and engendering trust
- Training and education
- Provisioning

As stated earlier, **intent** provides the basis for the entire mission. This intent does not necessarily have to be formulated by an individual. Moreover, the quality of C2 in this approach is looking for the existence of such an intent, how it is communicated among the participants, how the participants perceive and understand this intent, and also if they share this intent (Alberts & Hayes, 2006, pp. 38–40).

Determining roles, responsibilities, and relationships focus on another important aspect. The definition of these factors establishes a specific behavior among the participants, which is necessary to define patterns of interaction and is arguably one of the most important factors in disaster management (Alberts & Hayes, 2006, pp. 39–40). The quality of an organization can be determined by looking at the completeness of

the roles assigned, the existence of necessary relationships, and the common understanding among the participants of what is required from them (Alberts & Hayes, 2006, p. 41).

Rules and constraints are needed to define the boundaries of the endeavor. They can both be interpreted as fixed or variable (Alberts & Hayes, 2006, p. 42). Whereas fixed could be understood as given by culture, education, and, for example, organizational behavior, variable rules and constraints are more closely related to the specific mission (Alberts & Hayes, 2006, p. 42). Culture, especially during unexpected events, can have an important impact on managing the event mindfully (Weick & Sutcliffe, 2001, p. 124). Within a given organizational culture, individuals may share assumptions and values derived from these assumptions about how an organization should act (Weick & Sutcliffe, 2001, p. 121). Therefore, culture may hamper dealing with the unexpected and prevent mindfulness about the situation. As with the aforementioned function, the quality can mainly be determined by looking at how rules and constraints are understood and shared among the partners (Alberts & Hayes, 2006, p. 42).

Monitoring and assessing the situation and progress makes it possible to recognize and change the entire process if necessary (Alberts & Hayes, 2006, pp. 42–43). Therefore, its quality is measured by how well it determines if changes are necessary, how long it takes to recognize this need, if the adjustments are appropriate and made in a timely manner (Alberts & Hayes, 2006, p. 43).

Inspiring, motivating, and engendering trust is closely related to roles and responsibilities. Yet it should not be interpreted to mean the need for a charismatic leader to guide people. Instead these factors focus on the extent to which people are willing to participate and how such interactions between participants are carried out (Alberts & Hayes, 2006, p. 43). Arguably, this function has a huge impact on how resources and information are shared among participants.

Training and education is, as usual, a necessary function for encouraging the other functionalities. Especially new C2 approaches, required by new challenges, may require a certain type of education encouraging a different view on command and control.

Provisioning is an important functionality as it is in any endeavor (Alberts & Hayes, 2006, p. 46). The availability and timely allocation of resources is necessary to prepare for missions as well as to carry them out. To measure the success of C2 the effectiveness of resource allocation, in preparation as well as execution, has to be determined (Alberts & Hayes, 2006, p. 46).

b. Key Dimensions of a C2 Approach

Another important issue to understand this model is the definition of a space in which different approaches can be placed and assessed. Placing an approach inside this space does not mean it is where organizations would like to be, or they are considering being placed (Alberts & Hayes, 2006, p. 75). This assumption would misrepresent the intent of C2, because different endeavors might require different approaches, even in a disaster environment, and therefore, there is no right place to be (Alberts & Hayes, 2006, p. 76). Instead the goal has to be to become agile enough to choose between different approaches to best fit the mission. The three key dimensions of a C2 approach, as delineated in Figure 4, are allocation of decision rights, patterns of interaction, and distribution of information.

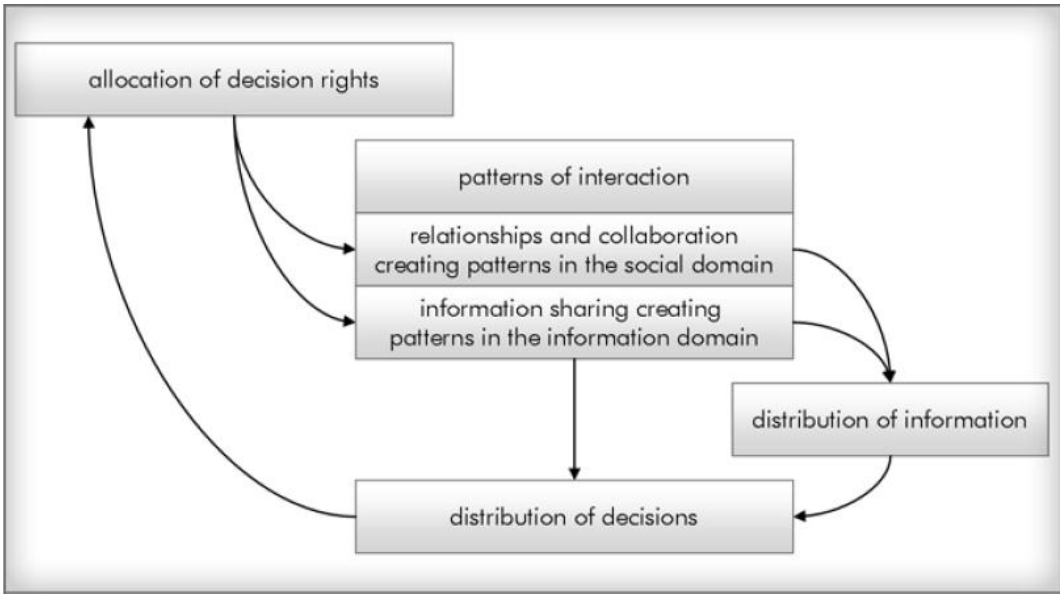


Figure 4. The three key dimensions of a C2 approach (from Alberts & Hayes, 2006, p. 82).

These key dimensions should not be understood as independent (Alberts & Hayes, 2006, p. 76). Rather, as shown in Figure 4, they influence each other. Allocating decision rights has immediate impact on the relationship between the participants and, therefore, on changing the patterns of interaction. Subsequently, these changes on the way information are shared among the organizations leads to the actual distribution of decisions.

Decisions are choices from among alternatives (Alberts & Hayes, 2006, p. 83). These decisions can be distributed among different realms, like functions, time, and echelons (Alberts & Hayes, 2006, p. 83). Furthermore, the allocation may range from total centralization to total decentralization of decision rights (Alberts & Hayes, 2006, p. 85). Especially military forces tend to decompose their decision-making along their established functional roles and, like other hierarchical organizations, tend to expect a chain of command (Alberts & Hayes, 2006; Denning & Hayes-Roth, 2006). In order to reach a high level of self-synchronization among participants, a high level of shared understanding is required (Alberts & Hayes, 2006, p. 86, Weick, 2001). The people closest to the event, with the most accurate information and knowledge, are best suited to deal with such an event. In particular, highly dynamic events are difficult to control from a distance (Kruke & Olsen, 2012). On the other hand, unplanned decentralization is as dangerous to a mission as total centralization (Kruke & Olsen, 2012). Research suggests that looking at the variety of organizations involved in future endeavors shared understanding might be hard to reach. Instead, the best to be gained is the replacement of "unity of command" with "unity of efforts" (Alberts & Hayes, 2006, p. 88).

As mentioned previously, patterns of interaction are dependent and guided by the allocation of decision rights. Alberts and Hayes specify three key elements in Information Age networks, namely: reach (the number and variety of participants), richness (quality of the contents), and the quality of the interactions enabled (Alberts & Hayes, 2006, p. 96). Organizations have to be careful to not just understand patterns of interaction as a means of connectivity between participants (Alberts & Hayes, 2006, p. 96). Rather, they should interpret this element as technological connections. It is a combination of all layers technological, processes, people, and organizations. Furthermore, these patterns

have not to be understood as fully connected networks, in which every node is connected with every other node. Instead research suggests that it is more important to use a wide range of media to build connections at several layers (Alberts & Hayes, 2006, p. 96; Palfrey, 2014, pp. 50–52). Different communication methods offer different levels of quality and are able to promote collaboration (Murray & Peyrefitte, 2007). However, it is necessary to figure out what has to be connected to accomplish a mission or, following the aforementioned argument, a shared intent (Palfrey, 2014,p. 53). But shared intent is useless if different skills and efforts cannot contribute to it (Adler, Heckscher, & Prusak, 2011). Therefore, the most desirable pattern is collaboration (Alberts & Hayes 2006, p. 96). As a matter of fact this also requires a change in how to distribute information in such dynamic situations. Traditional C2 approaches relied on pushing information, in which the originator decides who gets which information (Alberts and & 2006, p. 97). In disasters, this kind of centralized information pattern hampers success, and maintaining linkages to information in order to "pull" information at the local level becomes crucial (Waugh & Streib, 2006).

Patterns of interaction in Information Age C2 approaches can also be seen as networks (Alberts & Hayes 2006, p. 101). Therefore, Alberts and Hayes introduce four types of networks: fully connected, random, scale-free, and small-world networks. Fully connected networks are rare, due to the fact that every node in such a network has to be connected to all the others, which introduces scalability problems (Alberts & Hayes 2006, p. 102). Random networks are characterized by a large number of "hops" to get to any node and these networks are less clustered (Barabasi, 2009, pp. 49–52). Therefore, they are not very efficient. Scale-free networks are characterized by a small number of nodes with high connectivity, and most of these nodes have few interactions (Barabasi, 2009, pp. 209–212). Furthermore, they are efficient and resilient due to their nature of alternative routes and the existence of clusters (Barabasi, 2009, pp. 109–113). Figure 5 delineates the difference between both network structures.

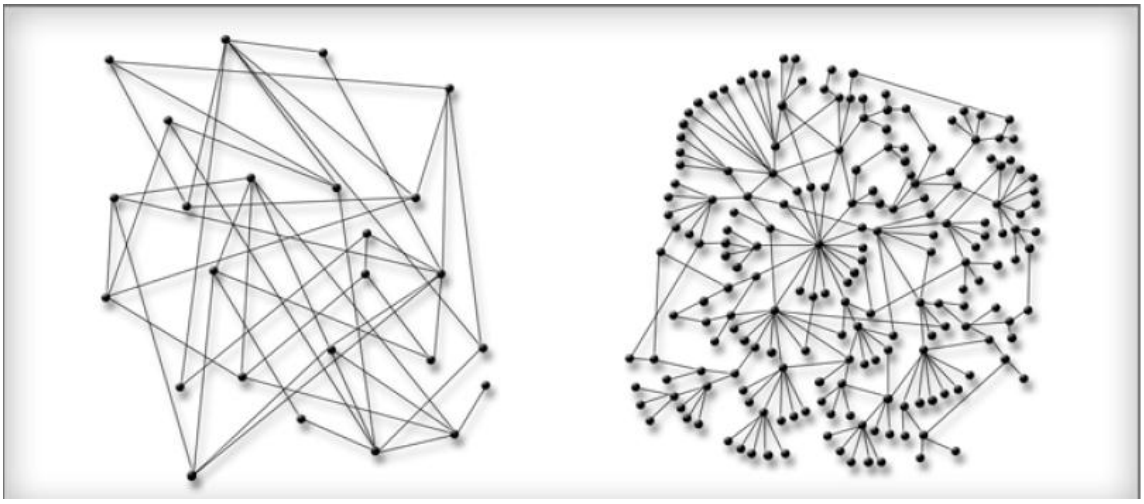


Figure 5. Comparison of a random network (left) and a scale-free network (right) (from Alberts & Hayes, 2006, p. 105).

Small-world networks are defined as the most efficient and richest network structures. Their structure is similar to scale-free networks. Although they do not have such long-haul linkages established, their clusters are much richer (Alberts & Hayes, 2006, p. 106).

Last, the distribution of information informs decision-making, and ultimately, the availability of all information at all times is the goal (Alberts & Hayes, 2006, p. 111). Despite having access to information, it is important to be able to identify the relevant information in time, even in a world where the number of sources of information is overwhelming (Alberts & Hayes, 2006, p. 111). The distribution of information can also be seen as a kind of feedback loop, following the patterns of interaction established and impacted by the distribution of decision rights (Alberts & Hayes, 2006, p. 108).

c. Conceptual Model: The Value View

The value view by Alberts & Hayes (2006, pp. 115–160) provides a framework to instantiate and organizes knowledge and is able to inform a variety of policy and investment decisions. Therefore, it is necessary to introduce the relevant relationships between the measures of merit depicted in Figure 6 in order to use these later on to examine the case. Arguably, all measures are important when looking at the specific command and control approach, but due to the focus of this research on the influences of

ICT to command and control, and not on the command approach itself, this research will only go into more specifics about the quality of information positions.

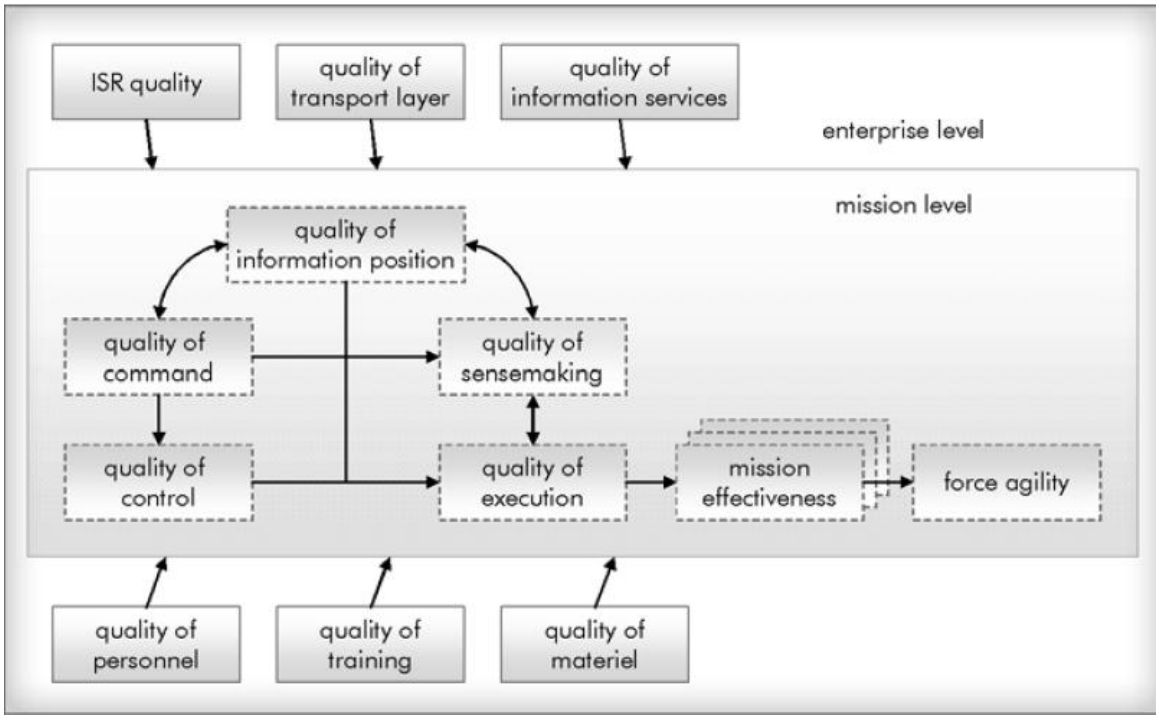


Figure 6. Value view (from Alberts & Hayes, 2006, p. 119).

As delineated in Figure 6, all measures of value add to the overall value of the process. However, most important to this view, and the later discussion, is the emphasis on the coevolution of different aspects, instead of focusing on increasing individual values separately (Alberts & Hayes, 2006, p. 118). As stated before, increased quality of information services, or technical possibilities to share information, does not necessarily improve either the quality of decision-making or the mission effectiveness. This is especially true if these processes do not support these improvements accordingly. The quality of information position has to be examined at all levels of organizations (Alberts & Hayes, 2006, p. 123).

Information in this context is the synopsis of data, information, and knowledge. Data can be seen as facts or observations without any context to a specific problem (Tuomi, 2000). If we provide context by organizing and restructuring data in order to

frame a specific problem we will receive information (Tuomi, 2000). Knowledge is then the result of processing this information framed by already established knowledge, concepts, or beliefs (Tuomi, 2000). Following this process, data becomes information, which becomes knowledge, which enables action (Nissen, 2006). The latter can also be seen as the starting point to turn around the hierarchy. According to Tuomi (2000) there are no isolated facts just lying around waiting to be processed. Instead knowledge has to be used to define problems and build a structure (information) in order to collect data accordingly. This happens, for example, when we decontextualize knowledge, structure it, and save and distribute data by saving them in databases (Tuomi, 2000).

The four main components of the quality of information position are information richness, information reach, information security, and information interactions. Information richness is best described by the amount of the available information, its accuracy, and for its actuality (Alberts & Hayes, 2006, p. 131). By contrast, information reach describes access to this information, or more specifically, how many participants have access to such information. Information security describes the related issues like confidentiality, integrity, and authenticity, as well as the non-repudiation of such information. Last, information interactions are focused on the forms, like data, video, or voice, and the nature of the communication, like pulled or pushed.

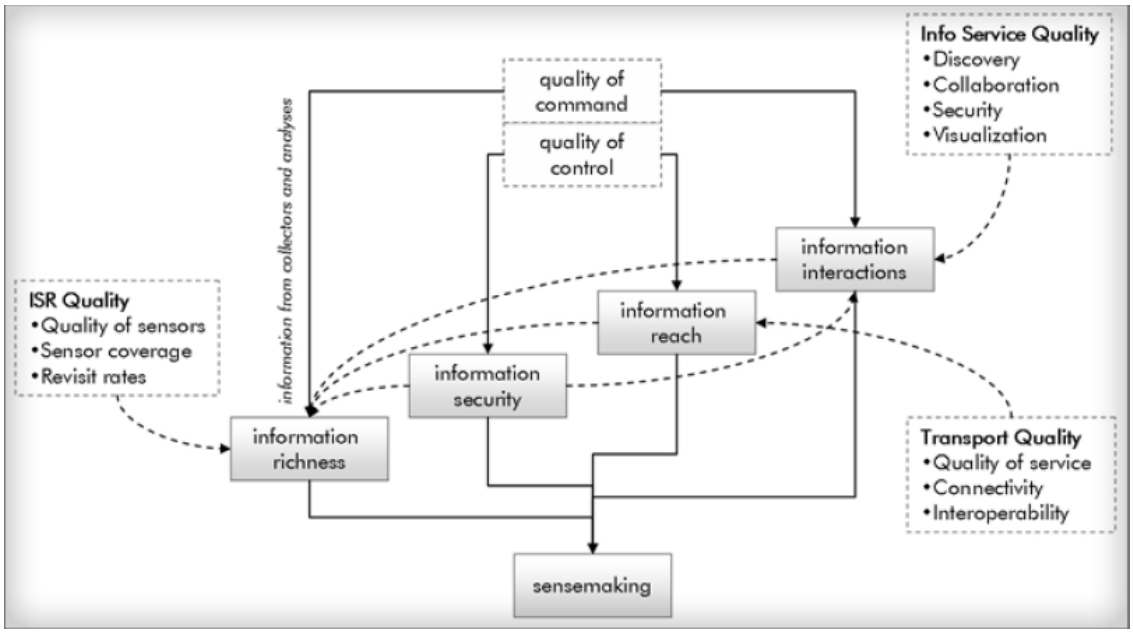


Figure 7. Information position components and relationships (from Alberts & Hayes, 2006, p. 131).

As delineated in Figure 7 these components interact with each other and are affected by the quality of ISR, transportation, and information services. The measures of merit for the quality of information position are outlined in Table 1.

Measure of Merit	Attributes		Description	Remarks
Quality of information position	Information richness	Correctness	extent to which information is consistent with ground truth	situation independent
		Consistency	extent to which a body of information is internally consistent	
		Currency	the age of the information	
		Precision	the degree of refinement, level of granularity, or extent of detail	
		Relevance	the proportion of the information that is related to the task at hand	situation dependent
		Completeness	the percentage of relevant information	
		Accuracy	the degree of specificity relative to need	
		Timeliness	the availability of information relative to the time is needed	
		Trust	the credibility of the information source	
		Confidence	the willingness to use the information	
	Information reach	Accessibilty Index	the proportion of the available infromation that is accessible	all
		Accessibilty Index	the proportion of the relevant available information that is accessible	relevant
		Index of shared information	the available information that is accessible by two or more members (COI, mission, or enterprise)	all
		Index of shared information	the available and relevant information that is accessible by two or more members (COI, mission, or enterprise)	relevant
	Information security	privacy		
		integrity		
		authenticity		
		availability		
		non-repudiation		
	Information interactions	Forms of Information		e.g., data, text, voice
		Nature of Interactions		e.g., internal, planned, pushed, pulled

Table 1. Measures of merit for quality of information position (after Alberts & Hayes, 2006).

The quality of information position affects sensemaking and, as stated earlier, is driven by command and control and vice versa. Sensemaking is how people and organizations frame problems in order to reach an understanding and to act accordingly (Alberts & Hayes, 2006, p. 134). This process of sensemaking is applied by either individuals or organizations and is based on awareness, knowledge, and understanding of the situation (Alberts & Hayes, 2006, p. 135). If a group of individuals or organizations is involved, then sensemaking is based on shared awareness, shared knowledge, and shared understanding (Alberts & Hayes, 2006, p. 136). As delineated in Figure 8 several factors influence collective sensemaking.

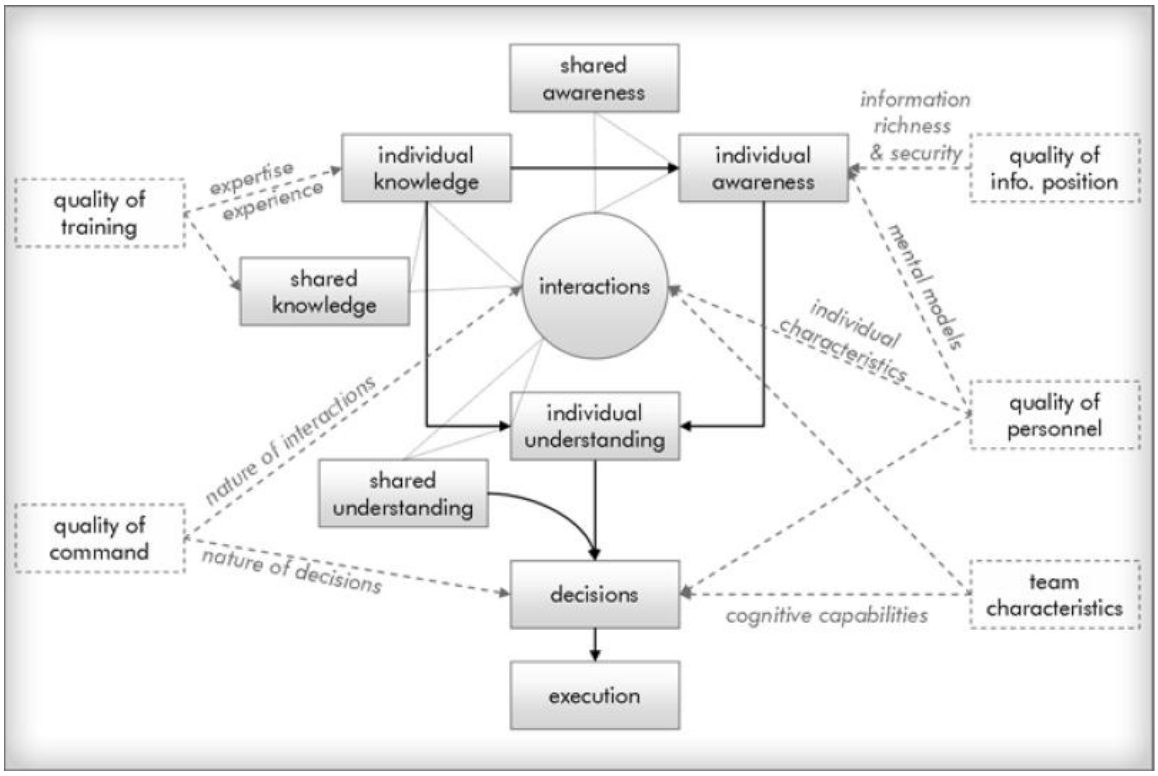


Figure 8. Collective sensemaking (from Alberts & Hayes, 2006, p. 136).

As outlined previously while discussing the key functions of command and control, command determines the roles and responsibilities of the organizations and delivers their shared intent, or shared purpose, and influences how individuals and organizations perceive sensemaking (Alberts & Hayes, 2006, pp. 137–138). This also has an impact on the quality of information position, as outlined earlier, by delivering information about the current situation and how information is distributed among the participants. Furthermore, training and education, as well as culture, have an impact on this process by bounding the space in which sensemaking takes place. Awareness is an individual's perception of the information about a situation (Alberts & Hayes, 2006, p. 140). It is, therefore, closely linked to the quality of information position, as this delivers the foundation of awareness. The measures for the quality of awareness and quality of understanding are summarized in Table 2.

Measure of Merit	Attributes		Description	Remarks
Quality of sensemaking	Individual awareness	Correctness	the extent to which awareness is consistent with ground truth	situation independent
		Consistency	the extent to which awareness is consistent with prior awareness	
		Currency	the time lag between the situation and awareness of it	
		Precision	the degree of refinement, level of granularity, or extent of detail	
		Relevance	the proportion of the awareness that is related to the task at hand	situation dependent
		Completeness	the degree to which awareness is sufficient to achieve understanding	
		Accuracy	the precision relative to need	
		Timeliness	the awareness attained relative to the time it is needed	
		Confidence	the willingness to draw conclusions based on awareness	
	Individual understanding	Correctness	the extent to which understanding is consistent with ground truth	situation independent
		Consistency	the extent to which understanding is consistent with prior understandings	
		Currency	the time lag between the situation and understanding it	
		Precision	the degree of refinement, level of granularity, or extent of detail	
		Relevance	the proportion of the understanding that is related to the task at hand	situation dependent
		Completeness	the degree to which understanding is sufficient for decision(s)	
		Accuracy	the precision relative to need	
		Timeliness	the understanding achieved relative to the time it is needed (decision)	
		Confidence	the willingness to decide based on understanding	

Table 2. Measures of merit for quality of sensemaking (after Alberts & Hayes, 2006).

Another important aspect is the quality of interactions, as argued by Alberts and Hayes (2006), which becomes clear by observing the central position inside the collective sensemaking process in Figure 8. As already discussed under the key components of the C2 approach, the nature of interactions influences all components inside the C2 approach (Alberts & Hayes, 2006, p. 151). Also mentioned earlier, the term "interactions" refers to a variety of interpretations and behaviors (Alberts & Hayes, 2006, p. 151). Due to its high relevance to this research, the respective attributes for the quality of interactions are summarized in Table 3. The attributes are stated as the maximum organizations are able to reach on a scale and can be seen as the ultimate goal for organizations.

Measure of Merit	Attributes		Description	Remarks
Quality of Interactions	-	Extent	Inclusive – all participants involved (collaboration cuts across organizational, functional, spatial, and temporal boundaries including echelons of command)	
		Access	Full and equal access – all participants have equal access to all other participants	
		Communication	Unconstrained – sufficient bandwidth	
		Level of participation	Participatory – all participants fully engaged	
		Frequency	Continuous – participants engaged without interruption	
		Synchronicity	Synchronous	
		Richness	Rich – multimedia, face-to-face	
		Scope	Complete – involves data, information, knowledge, understanding, decisions, and actions	

Table 3. Measures of merit for interactions and their attributes (after Alberts & Hayes, 2006)

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III. RESEARCH DESIGN

The primary research question for this case study is two-fold: "How do people, organizations, and processes interrelate in disaster relief missions, and how can organizations prepare for the effective use and procurement of technology?" The study will investigate this question by examining several reports issued after Hurricane Katrina. These reports provide insights to the response and mitigation efforts during this disaster and provide recommendations for the future. This allows the researcher to identify the role ICT played in this specific disaster management process, and according to the measures of quality derived from Alberts & Hayes (2006) to identify the relationship between people, organizations, processes, and technology. Therefore, this research is able to provide even more insights into this case by examining the reports from another perspective. This chapter discusses the case study in design, including its limitations, as well as the criteria for judging the quality of the research design.

A. CASE STUDY DESIGN

As stated earlier, the study represents a Type I case study (Yin, 2014, p. 50). According to Yin (2014) a Type I case study focuses on a single-case design and examines the global nature of a given case. A type I case study is reasonable for this research, because the Hurricane Katrina event is unique. Moreover, this event took place in one of the world's most developed countries and was handled primarily by national authorities. Therefore, the scope of this research, especially considering the relationships among organizations, is relatively (compared to other disasters) small. On the other side, as the impact of such a disaster to the socio-technical environment and the approach to mitigate these impacts are similar, insights created by this research are applicable to other disaster management efforts. Therefore, this study contributes to the overall body of knowledge on how people, processes, organizations, and technology interact with each other and how organizations efficiently procure and deploy ICT in disaster management.

B. CASE STUDY COMPONENTS

This case study design consists of four components: the study questions, the study propositions, and the unit of analysis.

Study questions: This case study focuses on the two-fold question, "How do people, organizations, processes interrelate in disaster relief missions, and how can organizations prepare for the effective use and procurement of technology?" This kind of question will help to identify the role of ICT in disaster management, in this case, the disaster management response to Hurricane Katrina. Furthermore, it will help to identify certain misalignments within the disaster management process.

Study propositions: Propositions direct attention to something that should be examined within the scope of the study (Yin, 2014, p. 30). The following propositions will bind the research, while examining the research question:

- The applied ICT is effective by itself, but lacks proper interoperability and necessary support by social interactions.
- The development of centralized decision-making counteracts the effective use of ICT.
- The applied connectivity among different actors does not represent the requirements necessary to deal with such situation.

Unit of analysis: The unit of analysis for this case study will be examining the Hurricane Katrina disaster management process against the C2 approach derived from Alberts and Hayes (2006). Identifying the key functions of C2 and assessing the quality of sensemaking, information position, and interactions in this specific case will inform us about the state of C2 during this event and shape recommendations that can be derived out of this knowledge. The evidence for this case will be solely collected through documentation, specifically reports filed after the incidents.

Logic Linking Data to Propositions: As stated by Yin, "The use of logical models consists of matching empirically observed events to theoretically predicted events" (Yin, 2014, pp. 155–156). As we examine the case against the C2 approach from Alberts and Hayes, logic models may be best suited to link the evidence found in the reports to the propositions identified in the C2 approach.

C. CRITERIA FOR JUDGING THE QUALITY OF RESEARCH DESIGN

To judge the quality of the research design, we consider validity (construct, internal, and external), as well as reliability.

Construct validity: According to Yin, construct validity is concerned with identifying correct operational measures for the concepts being studied (Yin, 2014, p. 46). The researcher uses the concept identified by Alberts & Hayes to examine the case. Furthermore, multiple sources of evidence are used to construct validity. The reports are chosen from governmental as well as non-profit organizations in order to remain unbiased.

Internal validity: Yin defines internal validity as "seeking to establish a causal relationship, whereby certain conditions are believed to lead to other conditions, as distinguished from spurious relationships (Yin, 2014, p. 46).

As the causal relationships in disaster management are complex and difficult to measure, they pose a threat to internal validity. The researcher draws from his knowledge of command and control in the interpretation of data. The researcher tries to mitigate them by using a logic model approach, to increase validity by comparing the case against the concept provided by Alberts and Hayes (2006). Furthermore, as the reports are already derived out from interviews with participants and research on primary resources, the research gains more validity.

External validity: The goal of the research design is for the findings of the study to be generalizable, or to define the domain in which the findings are generalizable (Yin, 2014, pp. 47–48). Because this research is based on reports following Hurricane Katrina, a high level of commonality is reached. This is because the majority of disaster management researchers agree on the process of disaster management. Furthermore, subject matter experts conducted the reports. Weaknesses with this specific case might be inherited. It does not incorporate any international cooperation, which is most often the case in other related studies.

Reliability: To ensure reliability, the same research can be repeated with the same results (Yin, 2014, p. 46). One factor in establishing reliability is the fact that the researcher has never been involved in any disaster management efforts and is unbiased referring to this topic. Second, as stated by Yin, the researcher documented the procedures followed in this case study to increase repeatability.

D. LIMITATIONS

The limitations of this study are that the researcher has no experience in disaster-relief operations and that only secondary data has been used. Validating the model through secondary data such as case reports needs to take into account the bias of the case reports.

IV. CASE STUDY

Hurricane Katrina made landfall on the Gulf Coast on August 29, 2005, as a category 3 hurricane (according to the Saffir-Simpson Hurricane Scale). Covering an area of about 103 miles around its center and reaching wind speeds up to 115 miles per hour, with gusts up to 130 miles per hour, Katrina was one of the most destructive natural disasters in U.S. history (Townsend, 2006). Katrina affected about 138 parishes and counties covering an area of about 93,000 square miles and caused 1,836 deaths (Townsend, 2006; Do Something.org, n.d.). Despite these tragic losses and the vast geographic distribution of damage, the impact of Katrina continued a trend that mapped increased financial damage with fewer fatalities, as depicted in Figure 9. The dark blue bars represent the number of fatalities, whereas the light blue bars represent the associated costs.

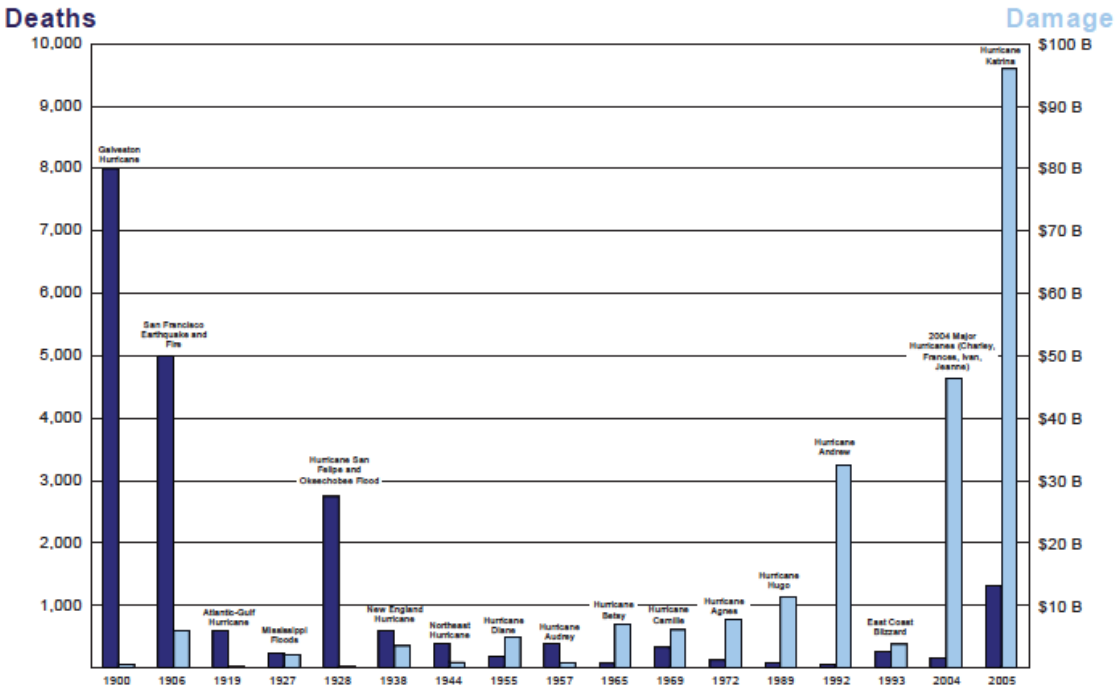

Figure 9. U.S. Natural Disasters Causing the Most Death and Damage to Property in Each Decade, 1900–2005, with 2004 Major Hurricanes Added Damage in Third Quarter 2005 Dollars (from Townsend, 2006).

A. IMPACT OF HURRICANE KATRINA

As suggested by the previously mentioned data, Hurricane Katrina was exemplary in showing the huge effect of cascading events. The fact that main parts of New Orleans are located under the main sea level and that the levee system failed during this disaster caused the flooding of about 80 percent of the entire city (Townsend, 2006). Arguably, the flooding caused more damage to the infrastructure than the hurricane may have caused independently. The huge impact of this disaster and organizational challenge of responding to it is underlined by the fact that about 770,000 people were displaced during this disaster (Townsend, 2006).

The impact on the communication infrastructure was significant as well. About 2.5 million phone lines were knocked down, 38 911-call centers were inoperable, about 40 radio and television broadcast stations were down (about 45 to 50 percent of the entire infrastructure), and about 2,000 cell sites went off service immediately after the incident (Kwasinski, Weaver, Krein, & Chapman, 2006; Townsend, 2006; Senate Homeland Security and Government Affairs Committee, 2006). Even one month after the incident 260,000 phone lines and 820 cell sites were still inoperable (Kwasinski et al., 2006). Despite the initial effects of the high wind speeds damaging antennas, severe damage was caused to the information infrastructure by the flooding. Although the flooding may not have caused all affected cell cites or central offices (CO) to fail immediately, the power outages that accompanied the flooding contributed to these failures (Kwasinski et al., 2006). In the aftermath, problems refueling some of the emergency generators added to the overall challenge posed by the damaged infrastructure. Appendices A to C provide an impression of the huge areas covered by these outages for the New Orleans area, their severity, and their causes. Summarizing, Kwasinski et al. came up with three main reasons for the devastating effects. First, the unusual strength of the hurricane, with its subsequent surge and following flooding of huge parts of the disaster area, affected the communication network as well as the power supply. Second, the centralized effect of the damages, which knocked out central nodes of the public switched telephone network (PSTN) and caused severe failures in the entire network, arguably did not have as significant an effect on the wireless network. Finally, the PSTN acted to a certain degree

as a single backbone and shared infrastructure (poles) with other services to impede the relief efforts as well (Kwasinski et al., 2006).

Looking at the severe devastation and the huge area affected it becomes clear that the local authorities would be unable to cope with such a disaster, although traditionally the responsibility to respond to such events is at the local and state level. By contrast, the federal government only plays a supportive role and acts as requested by the lower echelons (Townsend, 2007). Overall, 151 organizations, national and international, offered financial as well as materiel support to handle this disaster (House Committee on Government Reform, 2006). Without going into much detail, the following paragraph will outline the foundation on which the federal government and its organizations are involved in such disasters.

The Disaster Relief and Emergency Assistance Act (Stafford Act), reinforces the statement that foremost local and state authorities are responsible to ensure public safety. Additionally, it establishes a process to request federal assistance if necessary (Townsend, 2007). In the aftermath of 9/11 the National Strategy for Homeland Security requested an initiative to build a national incident management system and integrated all federal measures into a single plan (Townsend, 2007). The creation of the Department of Homeland Security (DHS) followed this strategy and the Federal Emergency Management Agency (FEMA) became a part of the DHS in 2003 following this strategy (Townsend, 2006). FEMA is the primary access point for state and local officials and has the primary responsibility for emergency response and recovery, although the organization itself does not have its own resources to deal with such incidents (Townsend, 2006).

The Homeland Security Presidential Directive 5 (HSPD-5) established a National Incident Management System (NIMS) and a National Response Plan (NRP) providing a national foundation on how the federal government organizes itself during disasters and how to support state and local authorities (Townsend, 2006). The NRP aims provide a flexible and scalable approach, as well as a systematic and coordinated approach to such disasters (Townsend, 2006). Therefore, the NRP should provide a unified command

structure for a coordinated federal, state, and local authority approach, as well as integrated non-governmental and private-sector organizations (Townsend, 2006).

B. ANALYSIS OF DISASTER RESPONSE MANAGEMENT

This section analyzes the role of communication infrastructure and the information sharing that impacted the disaster relief effort. Also analyzed are the information interactions of diverse groups participating in the disaster response and the lack of a coherent command operation view. Finally, command and control functions are examined in terms of the response effort.

1. Information Position

Keeping the devastation of the entire area in mind, access to information was extremely limited. This limitation's influence on the entire disaster relief effort was critical, because of the large number of public utility services that were destroyed or severely incapacitated (House Committee on Government Reform, 2006; Townsend, 2006). As mentioned before, one reason for this was the centralized effect on the communication infrastructure, but other factors, like unused communication means and network interoperability problems came into play as well. This led to situations in which, for example, the command center of one mayor had to wait for three days after Katrina made landfall to receive emails (Senate Homeland Security and Government Affairs Committee, 2006). According to Townsend (2006) several radios available from the U.S. Department of Agriculture (USDA) Forest Service were not utilized, although the availability of these radios was made known. From a different perspective, the fact that the Emergency Alert System also was not used by the states of Louisiana, Mississippi, and Alabama can be seen as a failure to use appropriate communication assets to disseminate information, in this case to the huge number of casualties (Townsend, 2006). Additionally, a lot of parishes cancelled their satellite radio contracts after the federal government cancelled the reimbursement for such services (Townsend, 2006). This left several local authorities without any means of communication (Townsend, 2006). Moreover, since 9/11 disaster management planners have identified that during incidents the communication between local responders is severely disrupted and the links between

federal, state, and local authorities are weak (House Committee on Government Reform, 2006). Recognizing this fact, it is astonishing that surveys conducted in 2004 reported 44 percent of emergency responses were hampered by non-interoperable communication systems, 49 percent of the cities were not able to operate with the state police, 60 percent were not interoperable with the state emergency operation center, and 83 percent were not interoperable with federal law enforcement agencies (House Committee on Government Reform, 2006). The fact that, for example, in the aftermath of Katrina the city of New Orleans and the Louisiana State police could not interoperate their radios, although the same radios operated well during the 2002 Super Bowl, underlines failures in the preparation for this disaster and the huge impact on the information position. Additionally, improper allocation of Mobile Emergency Response Support (MERS) detachments showed a lack in communication planning (Townsend, 2006). These mobile communication units with multiple data and voice communication lines could have brought visible improvement to the entire relief effort, but some of the available MERS were not located near the disaster area. Both facts are supported by the conclusion of the House Committee on Government Reform (2006) stating that the inability to connect multiple communications plans on federal, state, and local levels impeded communication and coordination.

Despite these negative facts the reports also stated some exemplary positive measures, which at least improved the relief efforts locally. First, Vanguard Technologies, Inc., provided two parishes with an innovative network solution, when no other organization was able to maintain service in this area. Furthermore, the company was able to build a fully operational wireless IP network covering 100 square miles within five days after the hurricane's landfall (Townsend, 2006). With this service, the local authorities were able to reassure their population and maintain services to coordinate the relief efforts (Townsend, 2006). Second, the Enhanced Digital Access Communication System (EDACS) from Harrison County remained nearly 100 percent operable (House Committee on Government Reform, 2006). Beyond the fact that this system remained operable, it was also able to link to similar systems used by the Florida State police, which enabled the communication to extend to two more counties in the

area. On the other hand, the system was not able to operate with FEMA systems at the same time (House Committee on Government Reform, 2006). Finally, the reallocation of one of the principal federal officers, onboard the USS Iwo Jima, into the port of New Orleans also increased the effectiveness drastically (Townsend, 2006).

Most recommendations made by analysts following the response to Hurricane Katrina address these failures by promoting increased mobile and diverse communication technology, enhanced regional capabilities, and a more efficient and transparent logistical system. Positioning of easily deployable and interoperable communication systems nearby the affected area should improve the response by reestablishing services soon after the incident (Senate Homeland Security and Government Affairs Committee, 2006). Also, the purchase of satellite phones is recommended on the state level to ensure communication capabilities inside the disaster area (Senate Homeland Security and Government Affairs Committee, 2006). Regional capacities should be improved by more capable organizational structures, incorporating staff members from federal, state, and local authorities, as well as a better integration of non-governmental organizations (Senate Homeland Security and Government Affairs Committee, 2006). A more sophisticated, transparent logistical system is recommended to improve the procurement and delivery of goods and services during emergencies (Townsend, 2006). Looking at the recommendations, the systems requested to improve disaster management cover information and knowledge management systems, emergency alert systems, medical/patient tracking systems, global information systems (GIS), and the aforementioned logistical systems (Senate Homeland Security and Government Affairs Committee, 2006; Townsend, 2006).

Already introduced and arguably applicable to information reach, as well as information richness, is the use of public communication means as an information source. Beyond that, the lack of widely distributed information through this channel also affected information reach and richness. During the disaster relief period, governmental organizations did not use public communication adequately and effectively (Townsend, 2006). Even more troubling, some officials inside the Department of Defense (DOD) used broadcast news to gain information about the disaster, especially about the condition

of the levees (Senate Homeland Security and Government Affairs Committee, 2006). This meant that several DOD officials did not learn about the failure of the levee system one day after, or even two days after the incident occurred (Senate Homeland Security and Government Affairs Committee, 2006). More serious than this effect on the timeliness of information was the effect on the consistency and accuracy of this information. The media was able to distribute uncorroborated information about the disaster without any intervention by authorities (Townsend, 2006). Moreover, as mentioned before, this information was used by DOD officials to make sense of the situation. Furthermore, the effect of these communication failures on the population cannot be underestimated. For example, ongoing reports about violent behavior in the Superdome, where the displaced were temporarily sheltered, hampered the relief efforts because drivers of supply trucks refused to drive to the Dome due to their fear. Furthermore, different use of language caused confusion at all levels of support. Especially, the misuse of the terms "breach" and "overtopping" caused confusion, because reporters and responders understood the terms differently (Townsend, 2006). Surprisingly, looking at this unclear situation, the willingness to use such information was quite high and the efforts to mitigate the harm caused by such false information were quite limited.

Although the reports do not go into much detail about the forms and nature of information, some facts can be gathered. Due to the loss of communication capabilities at the beginning, disaster management experienced a huge degradation with respect to the forms of information. Where phone and data communication were not available important information passed through radio channels instead (Senate Homeland Security and Government Affairs Committee, 2006). Because redundant communication systems were not available, most often this kind of communication was the only means available and finally overwhelmed the channels (Townsend, 2006). Even when communication was established, the form of communication slowed down processing of such information. On the other hand, face-to-face communication proved most valuable, especially in higher-level headquarters between decision makers (Townsend, 2006). Overall, communication was reduced to a few technical forms, which mainly did not

allow automation. Integrating information from one system into other systems was carried out primarily by hand (Townsend, 2006). This effect was observed at the local level and up to the state level, whereas higher command levels had access to more forms of communication. The recommendation to develop common software for logistics, GIS, patient tracking, and search and rescue underlines this finding, but even this software would not have improved the efforts at the local level without reliable communication. Looking at the effects of the hurricane on the infrastructure and the limited forms of communication available, as outlined, not surprisingly requests for information were mainly pushed from lower levels up to higher commands in order to fill the information vacuum. The perception that valuable information was not available at higher echelons for reliable decision-making resulted in recommendations mainly considering pushing information from local levels to higher commands, and distributing this information horizontally at higher commands. For example, recommendation number 33 of the Homeland Security and Government Affairs Committee (2006) stated that action request forms should be streamlined to request necessary assistance, and that federal and state systems should be interoperable. Also, number 35 of this report recommended an evacuee-registration system to share information among states.

2. Information Interactions

The extent to which communications reached all participating organizations was minimal. Townsend (2006) mentions that many organizations met roadblocks in their efforts to coordinate with other organizations. Especially private sector organizations faced this problem when trying to coordinate with federal agencies. As an example, the American Bus Association tried to find a contact at FEMA to coordinate bus schedules without success (Townsend, 2006). Another example is the Salvation Army not being allowed to send a liaison officer to the state's emergency operation center, which prevented them from obtaining critical information first hand (Townsend, 2006). But also between federal agencies flawed communication could be observed, even to the level that people in central and important positions purposely refused to transfer information (Senate Homeland Security and Government Affairs Committee, 2006). Furthermore, the inability of federal and state organizations to adapt their standard procedures to the

specific needs of this disaster was stated several times (Senate Homeland Security and Government Affairs Committee, 2006; Townsend, 2006). This inability severely impacted the efforts by slowing down processing of information and as a result several commodities offered to federal agencies even remained unused (Townsend, 2006). The inoperability issues discussed previously and the severe damage to the infrastructure also led to constrained communication, referring to the quality of interactions. The loss of communication channels and the lack of diversity in types of communication channels before the event caused a huge limitation in available bandwidth. The Senate Homeland Security and Government Affairs Committee report (2006) states that at one time hundreds of first responders had to compete for two radio channels, causing huge delays transmitting and receiving information. Another example provided by this report even mentioned that nearly 4,000 people were competing to use the highly constricted communication capacity. Especially at the local level and due to the damage to the infrastructure, the richness and scope of the interactions was also limited. As mentioned earlier, primarily only voice communication was available and even these channels were restricted in bandwidth. The available information was mainly imprecise and out of date, because it often required being input into several systems manually. This caused huge delays in responding to needs. Due to these poorly integrated systems and manual entry methods, the information available often led to a false perception of the situation. Summarizing, the lack of access to information and the limited bandwidth available to several relief organizations, and the lack of richness of interactions to transfer these data, had huge impact on the overall performance.

3. Sensemaking – Shared Awareness and Goals

> Without effective communications, every operation will suffer debilitating inefficiencies, some leading to ineffectiveness. (House Committee on Government Reform, 2006)

The aspects of a missing common operational picture and a lack of shared awareness are stressed in all the reports. As indicated by the aforementioned quote, a reason for the lack of shared awareness, shared understanding, and therefore sensemaking can be attributed to the lack of reliable communication available. As mentioned

previously, information builds the foundation for awareness and understanding. Considerable damage to this information flow will cause serious problems in establishing a common operational picture (COP). Despite the absence of critical and time-sensitive information, other factors are singled out by the reports as causing even more problems that added to the lack of situational awareness.

Differing hierarchical structures, lack of familiarity with other procedures, lack of knowledge about disposition of forces, and ambiguity about necessary information caused additional problems in building shared awareness. Hierarchical structures in this case had an impact on and was impacted by the fact that information was mainly pushed up to higher commands and by the fact that statements from higher officials were not requested. First responders delivered their information to higher commands in order to receive assistance, or to contribute to the COP. They never received information on the COP held by higher-level commands and therefore could not intervene to correct misperceptions due to the available information at the area of operation. For example, at high command levels the picture about the violent behavior at the Superdome forced decision makers to hold back necessary relief to this location. As these statements about violent behavior came in as late as September 6, while evacuations from this area had already taken place, the responsible persons at the Superdome never heard about these allegations and could not react (House Committee on Government Reform, 2006).

Secondly, hierarchical structures tend to listen to higher ranks and avoid countering their statements. For example, Governor Blanco stated at a mid-day videoconference on the day of the landfall that the levees had held. Contrary to multiple other reports starting at 9 a.m. that morning saying breaches of the levees had occurred, and several parishes were under water already (House Committee on Government Reform, 2006). Although this information was received by the DHS Homeland Security Operations Center (HSOC), a situation report distributed at 5 p.m. of the same day stated only a few of the facts and none of the urgency, and failed to mention the levee breaches at all (House Committee on Government Reform, 2006).

Another factor was the unfamiliarity that organizations had with each other's procedures (e.g., FEMA and USDA), which led to overseeing capabilities and resources of other organizations fitting the needs of the own organization (House Committee on Government Reform, 2006).

Furthermore, the disposition of forces was often times unclear and, therefore, possible sources of information remained unused. The director and the deputy director of the HSOC were not aware of representatives in New Orleans and at the Louisiana State Police Emergency Center, and as a result, several reports generated by these two persons remained unrecognized by the HSOC (House Committee on Government Reform, 2006).

Furthermore, situational awareness was impacted, because organizations failed to have clear policies on how and which information should be obtained, and to whom this information should be distributed. For example, the DOD lacked an information-sharing protocol, which impacted the situational awareness (Townsend, 2006). But also the DHS, and here explicitly the HSOC, was not able to define its information needs and its sources before the disaster (House Committee on Government Reform, 2006). As recommendation number 76 of the House Committee on Government Reform report summarizes these facts:

> The HSOC failed in its responsibility under the National Response Plan (NRP) to provide "general situational awareness" and a "common operational picture," particularly concerning the failure of the levees, the flooding of New Orleans, and the crowds at the Convention Center.

4. Key Functions of Command and Control

Several influences on the key functions of command and control (C2) could also be observed in the response to Hurricane Katrina. A lack of sufficient qualified personnel and inadequate training impaired command and control (House Committee on Government Reform, 2006). First responders were not able to utilize satellite telephones, because they were unable to operate them adequately (Senate Homeland Security and Government Affairs Committee, 2006). Furthermore, organizations had never trained to react to such destruction of their communication capabilities and, therefore, were unable even to assess the amount of destruction or to identify solutions to reestablish services

(Senate Homeland Security and Government Affairs Committee, 2006). Also most citizens were not prepared and sufficiently informed to cope with the storm and its aftermath. In particular, first responders had problems handling needs of persons with disabilities during the evacuation (Townsend, 2006). As outlined earlier the ability to monitor the ongoing operation was limited due to the destruction of the entire communication system on the local level. Furthermore, the federal government struggled to overcome these issues and was not able to provide a unity of command among different agencies (House Committee on Government Reform, 2006). In this case, the roles and responsibilities were not clearly defined. Worse yet, the institutionalized structure was annihilated and an alternative structure could not be developed. As stated previously, local and state governments are responsible to handle disasters at first and request support from higher levels if overwhelmed by the scale of an emergency. In this case the local responder structure had been destroyed immediately and the state government was incapacitated, and thus, the federal government had to take over a new role, or try to establish a new structure (Townsend, 2006). However, the federal agencies were not trained or prepared for such intervention. Furthermore, even within the DHS and within several other federal agencies, the command centers had overlapping and competing roles and responsibilities, which were exposed as flaws of the C2 process (Townsend, 2006). For example, the report of the House Committee on Government Reform (2006) mentioned that despite advice from FEMA, DOD frequently acted on its own, accepting missions immediately from local authorities without consulting FEMA first. Also, some violation of rules occurred immediately impacting the intent of the mission. HSOC provided situation reports every 12 hours. Additionally, they provided Spot Reports outlining specific events, which required immediate attention. However, these requests for assistance were not stated directly in the Spot Report due to the wide range of recipients of the report (Senate Homeland Security and Government Affairs Committee, 2006). In ignorance of the importance of these Spot Reports and perceiving the situation reports as more authoritative, agencies failed to realize the New Orleans flooding until more than 12 hours later, when they received the 5 a.m. situation report on the day after landfall (Senate Homeland Security and Government Affairs Committee,

2006). Despite the ambiguity of the rules for this disaster, it also shows that the HSOC failed to provide intent to other participants necessary to align efforts by providing a COP. Finally, provisioning also impacted the command and control of Hurricane Katrina. All reports stated that during the investigation of the disaster response witnesses often testified hearing about the insufficient funding for interoperable communication devices. Furthermore, lack of prioritization, poor coordination between organizations, and frequent internal debates are mentioned as hindering a more reliable communication structure (House Committee on Government Reform, 2006). This conclusion does not hold at all when looking at the cases in which these obstacles could be overcome. This is underlined by the huge amount of funding flowing into the states for equipment. Since 2001, $8.6 billion were spent on equipment, training, and exercises (House Committee on Government Reform, 2006). It should also be noted that the communication infrastructure in Alabama was considered far better than in Mississippi and Louisiana, by providing various capabilities, redundant backups, and a high level of connectivity (House Committee on Government Reform, 2006). Another factor related to funding and provisioning was that local authorities simply underestimated the use of communication technology and its importance for disaster relief. Louisiana and New Orleans introduced and paid for satellite phones for several parishes until they stopped paying the monthly fee. All but three parishes returned their phones afterwards to the states, due to their unwillingness to pay the bills (Senate Homeland Security and Government Affairs Committee, 2006). Arguably, this can be interpreted as insufficient funding, but looking at the small amounts necessary for this technology and by observing the value of such devices when conventional communication breaks down, it is more a problem of setting wrong priorities.

C. OUTLINING THE FRAMEWORK

The following paragraphs review parts of the findings and recommend a framework organizations should follow to improve current systems and procure new ICT in disaster management. Not all findings previously discussed are immediately related to ICT, but as outlined before, only a holistic view can improve command and control.

Therefore, where suitable, the benefits of introducing new ICT will be outlined, as will the activities necessary to integrate such technology.

One theme that runs like a common thread through the case is the huge devastation to the communication structure inside the disaster area and the impact on command and control. By cutting out the first line of response, the immediate relief efforts were severely hampered. Furthermore, the entire structure of command and control was influenced by this event. State and federal authorities were facing huge information gaps, due to the loss of communication with lower echelons. The given command structure was unable to react to this situation in a flexible way and even the state authorities were cut off to a certain degree and the capacity of their additional infrastructure was limited. Another effect caused by the loss of communication at the lower level was an information vacuum at higher levels. As a result, lower levels were compelled to support such information demands. Therefore, less information reached first responders, making it even harder to coordinate at the front line without knowledge about what was happening at other parts of the area.

Second, the lack of shared awareness and shared understanding seriously impacted the whole relief effort. Again, seriously affected by the loss in quality of the information position. Additionally, the unclear roles and responsibilities and the inability to interoperate with other systems affected the entire approach. Because of unclear responsibilities, organizations were unable to adapt to this new situation. The common way to operate together was severely impacted and new ways could not be determined in this short timeframe. This was mainly because several organizations waited for a central leadership, were unwilling to cooperate, or even did not know with whom to coordinate. As a matter of fact, a common thread running through the recommendations and findings of all three reports is the need for a more centralized command structure, able to take over command and deliver situational awareness for the entire structure, or parts of it.

> Establish a National Operations Center to coordinate the National response and provide situational awareness and a common operating picture for the entire Federal government. This interagency center will allow for National-level coordination of Federal/State/local response to major domestic incidents. (Townsend, 2006)

> Create a New, Comprehensive Emergency-Management Organization within DHS to Prepare for and Respond to All Disasters and Catastrophes. Hurricane Katrina exposed flaws in the structure of the Federal Emergency Management Agency (FEMA) and the Department of Homeland Security (DHS) that are too substantial to mend. We propose to abolish FEMA and build a stronger, more capable structure within DHS. The structure will form the foundation of the nation's emergency-management system. It will be an independent entity within DHS, but will draw on the resources of the Department and will be led and staffed by capable, committed individuals. (Senate Homeland Security and Government Affairs Committee, 2006)

Finally, the systems requested by all the reports are mainly concerned with information and knowledge management systems, emergency alert systems, medical/patient tracking systems, global information systems, and logistical systems. None of these systems is new to the field of disaster management and all are widely used in different organizations. Thus, we may conclude that organizations trying to improve disaster management are not necessarily looking for new software developments. More important is the way to integrate these systems and ensure that they interoperate with other systems.

1. Define the Area of Operation of an Organization

This first step of the framework defines the essential foundation of the ICT used in disaster management. The requirements for organizations operating at different levels of a disaster relief operation differ in their intent as well in how they are impacted by disasters. For this framework we would imagine three levels of areas of operation similar to the case represented. First responders and organizations immediately acting in the area of impact after the incident situated at the local level. The regional level, or in this case the state level, represents the next higher echelon in this hierarchy. Finally, the national, or federal level, is responsible for higher-level command and control. As outlined by the case, the local level was highly affected by the disaster and this might be the case in nearly every disaster. Organizations acting on the local level have to assure a high robustness and high interoperability for their systems. High robustness has to be interpreted as several ways of communication (e.g., wired, wireless) and also forms of communication (e.g., data, voice). Despite the robustness of communication, local level

organizations should also consider power outages and be prepared to power at least their own system for a certain time by generators, or for example, by renewable energies, if applicable. ICT structure at this level has to be flexible, but not ad-hoc, in the sense of being established when needed. Interoperability with similar organizations acting in the same area is a necessary demand to improve coordination and collaboration during disaster relief efforts. With respect to financial constraints and organizations running a variety of legacy systems this might be challenging, but it is a necessary demand. When possibilities to interoperate with other organizations are identified, tests and exercises are needed to train personnel. For the regional level organizations to succeed, they must establish connections to similar organizations at this level and connect to these systems where possible. Considering these connections, organizations should examine already established connections and carefully decide which connection is most useful, not necessarily for the organization on hand, but for the relief efforts. Multiple connections are necessary as well, but the degree of connectivity required at the regional level is much less than at the local level. Although it may sound promising to connect to a particular organization that has already established a lot of connections, it is much more useful to reach out to as many organizations as possible. Therefore, a clear understanding of all connections should be derived, providing a better foundation for a decision. Organizations may not only operate at the regional level, as can be seen in the case, where the state provided several elements (State Police, National Guard) in the area of the disaster. Therefore, connections to these local clusters have to be established and configured similarly with respect to robustness. Organizations at the national level need to connect to multiple regional nodes, but not necessarily to a lot of other national organizations. Arguably, the number of players at this level is low. Considering these connections, the necessary bandwidth has to be kept in mind, as well as the capacity of such connection points, or operation centers (OC), as well. For sure, throughput at the local level should be expected as the lowest. Therefore, for example, applications running at this level should only request small amounts of throughput. The uplink to the regional level has to be designed to incorporate more than the data transferred by the organic parts of the system, because integrating other systems might dramatically increase the

necessary bandwidth. Regional level organizations have to consider their bandwidth also carefully, but due to the fact that the impact of destruction to the regional OC might be not that significant; they may already reach back to commercial infrastructure. However, a considerably powerful backup is necessary. Of greater concern should be the capacity and equipment of such regional OCs. As shown by the case study, new unexpected participants in the disaster relief operation have to be incorporated at this level. The network and communication capacity at this level should not be established at the current level of participants; moreover network and communication capacity should have a sufficient level of redundancy. National level organizations may have the most stable demands, as the effect of the disaster should be relatively low at this level and the rate of change to the participants might be low as well. Essentially, there is the certain eventuality of a disaster affecting even the national OC, so at least one backup should be established capable of handling a similar amount of bandwidth as the primary link.

2. Identify the Main Area of Organization's Expertise

Initially this sounds obvious and not very important for disaster relief efforts, but it establishes roles and responsibilities when linking to other organizations and helps to identify information needs as well as information sources. This fact is even more important if organizations do not necessarily perceive disaster relief as their primary objective, as in the case of the DOD. Defining which specialization an organization has, determines to a great extent to which organizations connections should be established. Just by the fact that similar organizations are acting in the same field should establish a common understanding more easily. Organizations acting solely at this level, for example, department stores offering support, should also attempt to identify local authorities with similar specializations, or at least those who share a demand for the information offered. This prevents roadblocks during disasters. By establishing this connection in advance planners can define the relationship between these organizations in a way that is visible to all other participants. Looking at this approach from another perspective, organizations at this level with specific needs should look out for organizations able to provide such needs and try to integrate their information accordingly. Furthermore, when establishing connections to higher levels of command

the specialization of an organization will immediately determine what information the organization may need and what information the organization can provide. For example, if an organization's main specialization is supply chain management and it is holding commodities useful for disaster relief, this organization's information mainly concerns where these commodities are stored, how much of these goods are on hand, and if there is transport capacity available. Conversely, this specialization also defines clearly which kind of information the organization will need. Mainly, that information is where these commodities are needed and how they could approach this area. Although not an exhaustive example, it should show the idea behind this step. Even more important, this step defines the particular level of security for the information. Although it was not discussed in the case in detail, due to other more apparent issues, the security of data and perhaps the system behind these data have to be protected. For example, patient-tracking information should require a certain level of security. Identifying this level of security will enable easier distribution of and allocation of access to such information, instead of trying to determine such policies and procedures during the disaster. Furthermore, the information provided for disaster relief may represent a certain degree of information available in such a system. Defining which information can be exchanged and identifying the appropriate interfaces up front establishes also security for the information system supplying support for disaster relief. By defining information demands when connecting to other organizations, an entity can implicitly state its role and responsibility to a disaster relief effort. Additionally, by doing so an organization's information can be delivered in a more structured manner and the organization's system may be able to deliver this information through a converter to adapt to more modern systems and maintain legacy systems until new standards are incorporated.

3. Make Information Available to All Connected Levels

Information needs to be distributed to all levels involved in disaster relief efforts, not only to higher or similar levels of command. This especially enforces the capabilities of first responders, where the greatest effect on disaster relief will be achieved, according to the findings of the case. Furthermore, information should not be distributed solely inside of an organization. Information has to be distributed to other organizations as well.

Therefore, a state of equilibrium should be reached between externally distributed information and available information inside the organization. This also is a way to distribute trust among the participating organizations. Providing information to all levels follows also the principle of pulling information if necessary. For example, first responders may face limited bandwidth at one time and may switch off certain information available to their devices in order to maintain the relevant traffic. If the bandwidth later on can be increased, more information can be pulled and helps first responders to anticipate other actions nearby and implicitly helps to understand the common intent. Furthermore, these necessary messages providing the intent have to be distributed to the lowest level if possible. Here the definition of an organization's primary expertise helps to define which information must be available at the respective level. It is also pertinent when purchasing a new system to define the possibility of turning off information. Defining interfaces in this manner will help to identify different procedures and patterns among partners, which may encourage organizations to adapt to another's procedures, or at least increase the level of understanding among partners. Furthermore, these initial measures can help to identify a common standard and increase the ability to incorporate even more participants. Finally, identifying the specification of interfaces to other systems, should encourage organizations to test, train, and evaluate such information exchange instead of expecting systems to work together based on some technical specifications. Interfaces might be able to establish a connection, but they may not necessarily enable the exchange of information or, at least, not the relevant information.

Arguably, there are always limitations on how far interoperability, interconnectivity, and information sharing can be established. In times of financial austerity the purchase of new systems might not even possible. However, even in this case, following this framework will enable organizations to assess their current systems and better understand the implications these systems may have for other factors of command and control. Moreover, this framework is only approachable by searching for connections to other participants up front, instead of focusing on specific connections. The goal is to build robust clusters at the local level with several connections to other

participants at this level and establish uplinks to regional authorities. This will now enable authorities at the local level to request assistance from higher levels and contribute to their COP. Moreover, it will enable local level organizations to reach out to several other clusters acting in the same area and participate at the COP from these organizations. This might enable all disaster relief effort participants to gain a better understanding of the entire process, the different cultures involved, and the needs and sources of other organizations. Furthermore, this kind of approach encourages training and exercises with a variety of organizations to support the findings and therefore is able to intensify relationships and define roles and responsibilities. Arguably, these are all factors influencing effective command and control. Following this approach, organizations can also have an impact on the procurement strategy as well. Focusing on the necessary connections and information flow is an expression of a more service-oriented procurement policy. As mentioned before, connections should be formed not solely to the best-connected organizations. Instead of using the ICT assigned to the strategy of one's own organization, the best-suited connections to promote the services are in focus. This might be a challenge for organizations engaging in different local and regional areas due to the different connections and interactions required. Furthermore, often consent might be hard to reach, but even in this case, the approach helps organizations to identify promising connections and to guide future procurements aiming for better disaster relief efforts. Finally, in contrast to the recommendations for a more centralized structure of command and control, the intensified distribution of information and ties to other organizations should strengthen especially the local level and bring higher echelons into a more supportive role.

V. CONCLUSION AND RECOMMENDATIONS

A. SUMMARY

This research explored the use of ICT in disaster management—specifically as it relates to the interactions between people, processes, organizations, and technology. In particular, this thesis examined the two-fold research question "How do people, organizations, processes interrelate in disaster relief missions, and how can organizations prepare for the effective use and procurement of technology?" The application of ICT promises a huge benefit to disaster relief operations, by enabling a timely acquisition and distribution of information among participants. This promises increased situational awareness and is able to improve disaster relief efforts. Applying technology in any kind of command and control has interrelations with other factors, so they may cancel each other out. Understanding these interrelations and their effect on command and control is necessary to improve the use of ICT. The foundation of this study was provided in Chapter II through a literature review of the underlying concepts of disaster relief and the introduction of the command and control approach from Alberts and Hayes. Chapter III described the research design and considerations for using a case study approach for this study. Chapter IV introduced the case of Hurricane Katrina and harnessed the command and control approach by Alberts and Hayes introduced in the literature review to analyze case evidence collected by observations of quality of information position, quality of interactions, quality of sensemaking, and the key functions of C2. The analysis illustrates that despite the availability of ICT, it is possible to lose quality of information position, and due to unclear definition of roles and responsibilities, situational awareness and, consequently, relief efforts can be seriously impacted.

B. CONCLUSION

Guided by the findings of the case study, a framework was developed to enable leveraging of command and control and mitigating the impact of a disaster such as Hurricane Katrina.

Huge devastation to the communication infrastructure in the area of operation had serious implications on the entire command and control of the disaster relief efforts. This loss of quality of information position at the local level hampered all efforts at this level and resulted in a loss of situational awareness at higher levels. This loss of awareness caused misperceptions and serious delays in relief efforts. Therefore, as part of disaster relief preparation and planning, this study recommends organizations identify their area of operation in advance and adjust their ICT accordingly. As shown in this research, the local, regional, and national levels require different aspects of ICT and each level has unique capabilities to interconnect and interoperate with other systems. While local levels need robust communication infrastructures and high interoperability to enable the exchange of information after a disaster impacts this area, higher level commands and their communication networks might less heavily impacted and would require fewer connections. However, the connections at the regional level must be able to interconnect the clusters at lower levels. These connections are able to provide an increased information reach by connecting independent clusters. Furthermore, redundancy, if two different regional OCs can reach for example the same local cluster through different communication means.

Additionally, the fact that roles and responsibilities were not clearly defined in the aftermath of Hurricane Katrina also hampered the disaster relief efforts. The systems requested by the case study were not new to the field of ICT in disaster relief efforts. Moreover their interoperability and integration was pointed out as factor for improving command and control. Therefore, organizations need to identify their core capabilities in disaster relief in order to identify necessary linkages to other organizations at their respective level and to other disaster management levels. By identifying these connections, organizations are able to define their information sources and demands in advance, are able to establish connections to other organizations in advance, and,

therefore, are able to articulate their roles and responsibilities in disaster relief efforts. Especially, this is a necessary step for organizations like the DOD, where disaster relief efforts are not the primary mission of the organization.

Losing the lower level of command and control during Hurricane Katrina pushed the demand for information and the availability of information to become focused at the higher command level, which left lower levels without much information. Information needs to be available at all connected levels. Following the identification of which information is needed and which can be distributed, the organizations must provide such information to all levels. Thus, knowing these needs helps to identify in advance the bandwidth required to share the information among organizations, and it establishes trust among partners. Furthermore, this exchange with other organizations helps all participants in disaster relief to understand the others' procedures and behaviors. This information could never be gleaned by just looking at the technical specification of interfaces.

The framework presented in this case study adds to the body of knowledge by incorporating reflections about the interrelations of ICT to the procurement process and to the use of ICT in disaster management. Assessing the current procurement process of ICT with this framework and establishing connections along those recommendations will enable a more robust and interconnected network. It will shift the procurement focus of ICT to a more service-oriented approach, with a greater unity of intent, instead of using ICT to assist the strategy of an individual organization. Moreover, roles and responsibilities are defined as well as information demands and sources are formulated. Following this approach, planners can leverage the use of ICT in disaster management, by eliminating major factors negatively affecting command and control.

C. RECOMMENDATIONS FOR FUTURE RESEARCH

The results of this research provide a generic framework to counterbalance the findings of this specific case. In order to validate this framework, other cases should be examined. Especially, this case was bounded by one nation responding to the disaster. The implications for this framework when disaster relief efforts involve the participation of international organizations may totally differ. Furthermore, if the devastation at the local level is not as extensive as in this case study or if damage occurs at central points at the regional level, it might lead to complementary findings. Moreover, the framework provides only generic steps to improve command and control. Future research could focus on specific organizations following this approach and identifying changes to current ICT, or assessing the applicability of current ICT to this approach. Furthermore, a more detailed examination of how this approach is able to shift the ICT procurement strategy in specific organizations might be addressed.

APPENDIX A. BELLSOUTH OUTAGES DAYS/WEEKS AFTER KATRINA

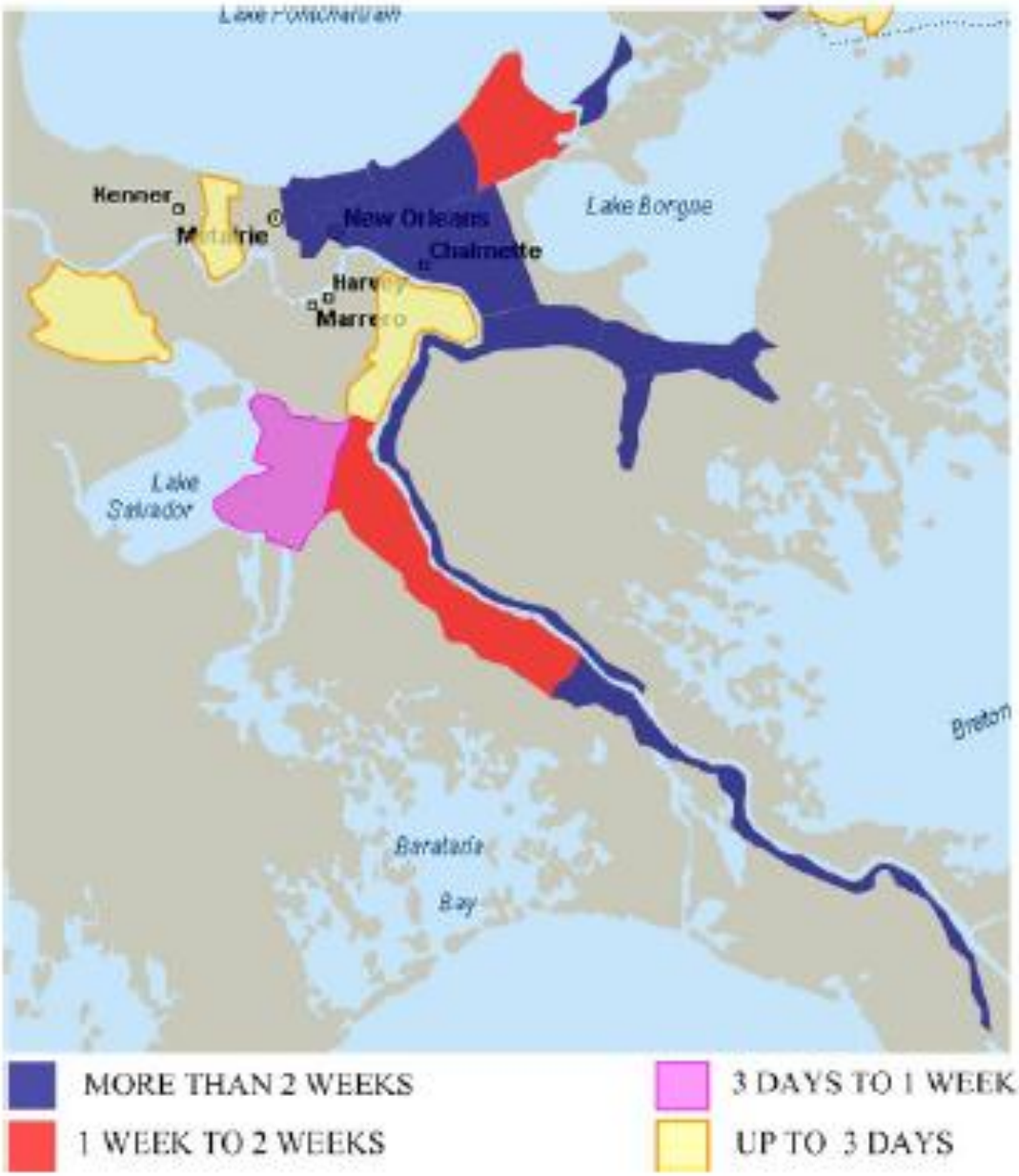

Figure 10. Failed BellSouth CO regions in New Orleans and outage severity (from Kwasinski et al., 2006).

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APPENDIX B. BELLSOUTH OUTAGES AND RELATED CAUSES

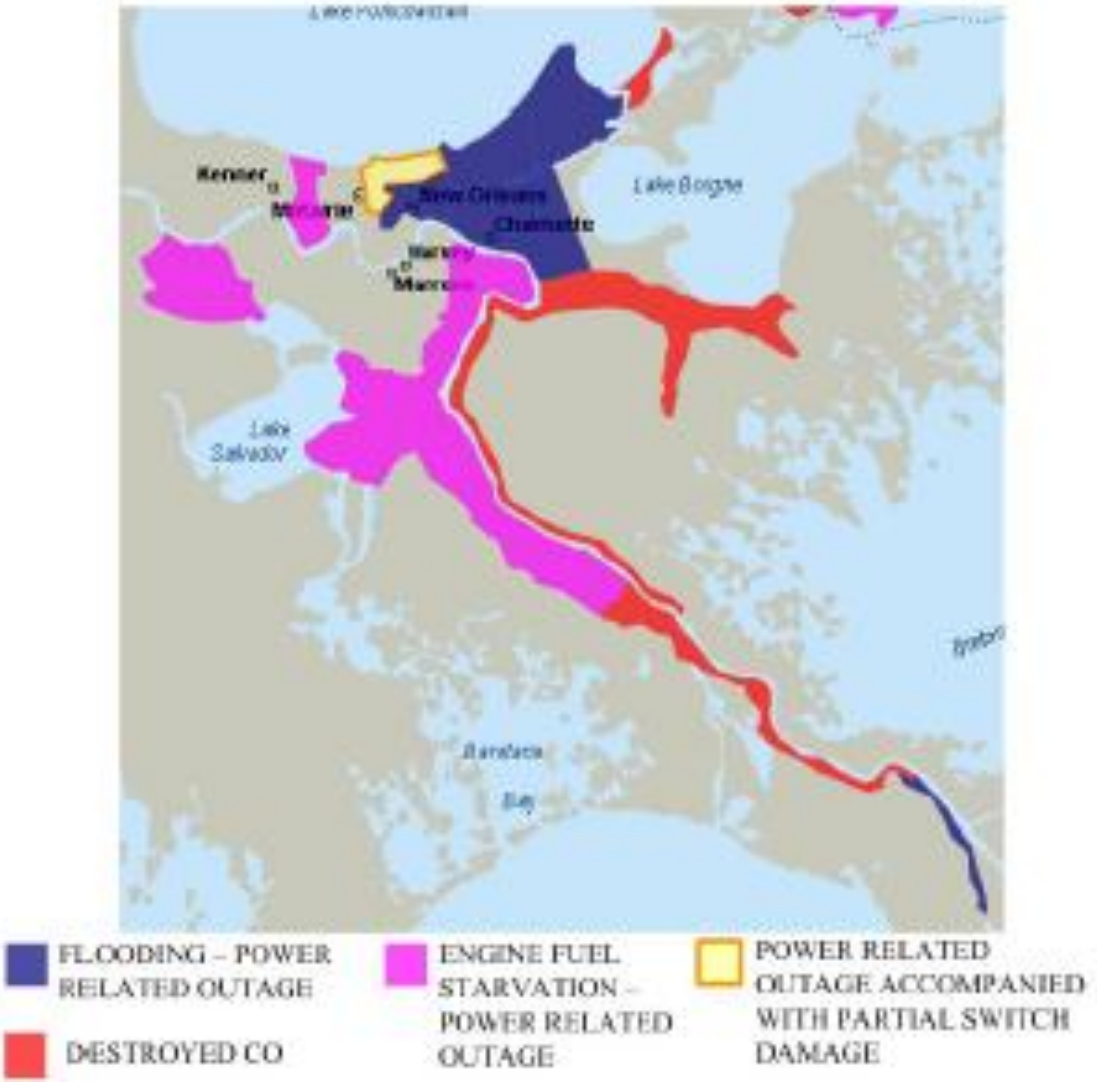

Figure 11. BellSouth failed CO regions around New Orleans (from Kwasinski et al., 2006).

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APPENDIX C. CELL-SITE FAILURES AND RELATED CAUSES

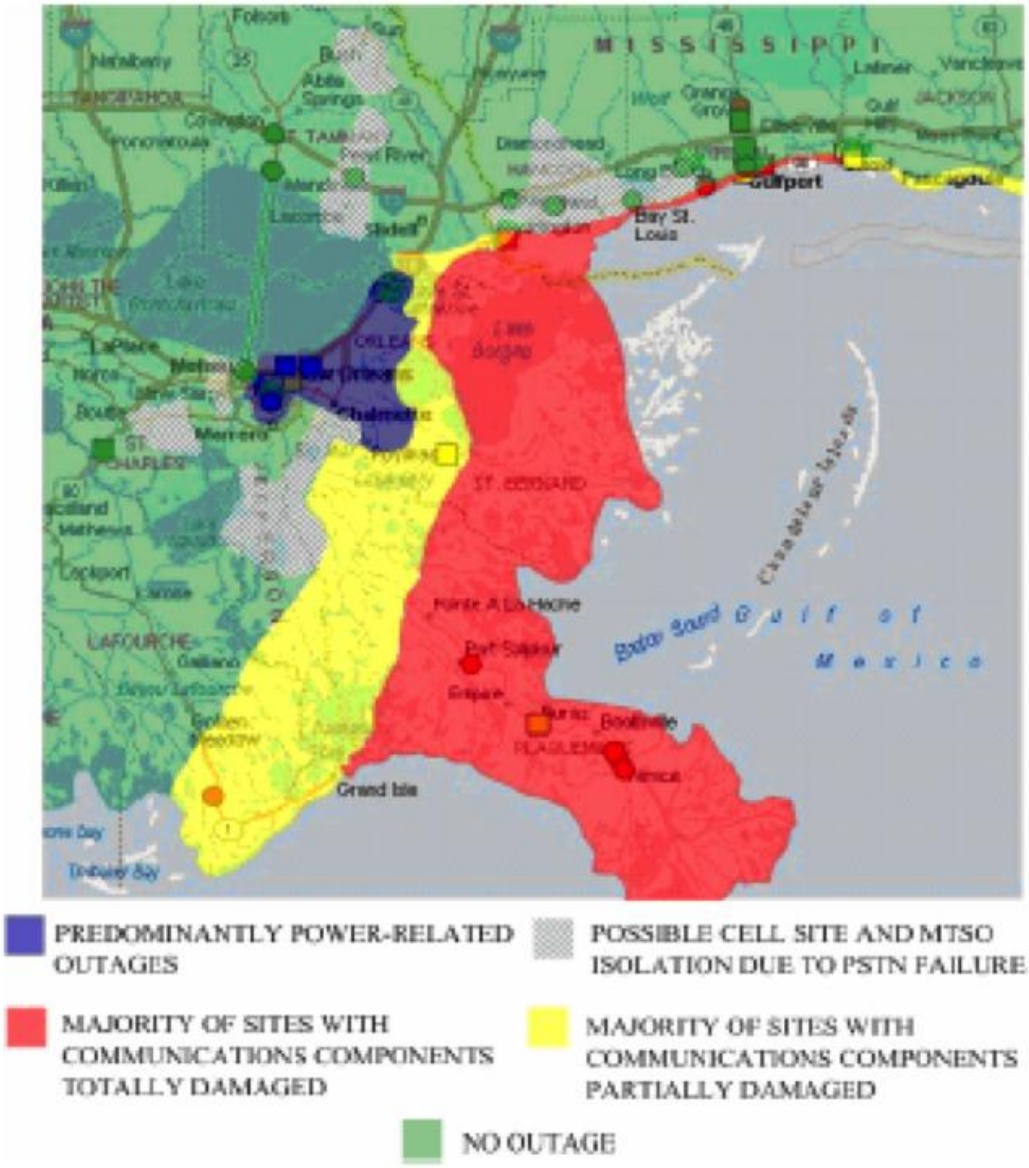

Figure 12. Analyzed cell-site locations with predominant cause of failure (from Kwasinski et al., 2006).

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